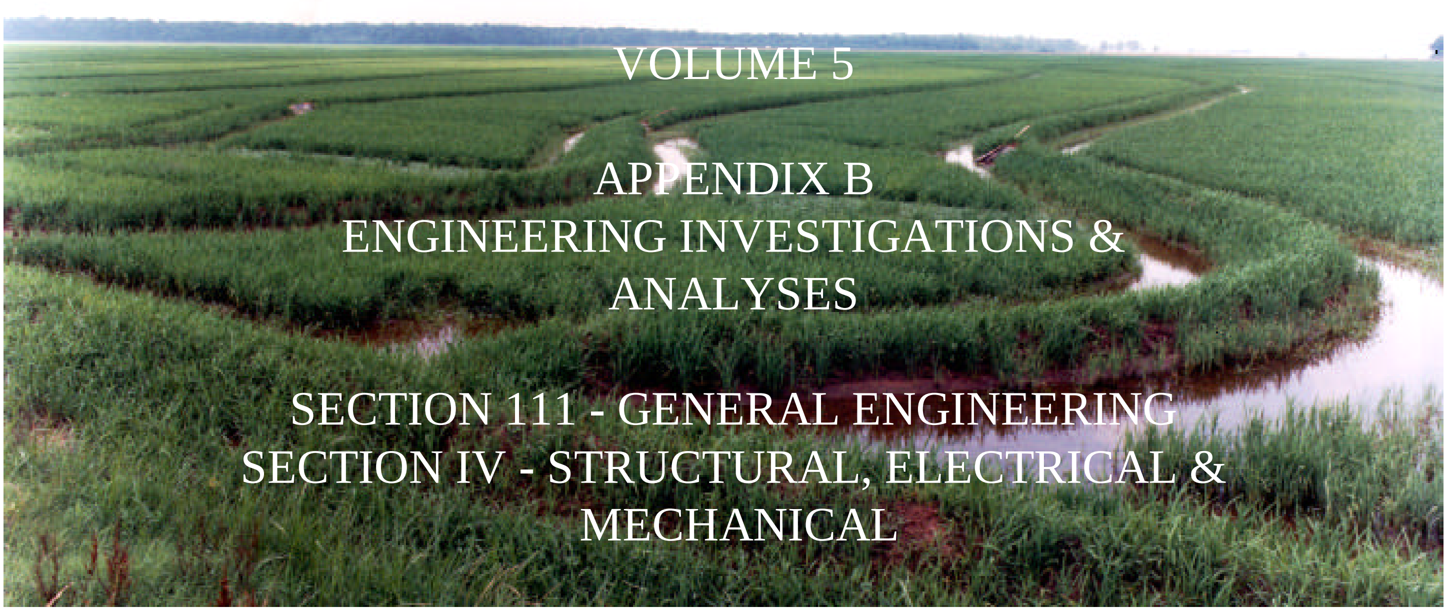
**US Army Corps of Engineers**
Memphis District
Mississippi River Comission

# EASTERN ARKANSAS REGION COMPREHENSIVE STUDY

## GRAND PRAIRIE REGION AND BAYOU METO BASIN, ARKANSAS PROJECT

## GRAND PRAIRIE AREA DEMONSTRATION PROJECT

## GENERAL REEVALUATION REPORT



VOLUME 5

APPENDIX B
ENGINEERING INVESTIGATIONS & ANALYSES

SECTION 111 - GENERAL ENGINEERING
SECTION IV - STRUCTURAL, ELECTRICAL & MECHANICAL

# GRAND PRAIRIE AREA DEMONSTRATION PROJECT
## GENERAL REEVALUATION REPORT (GRR) INDEX

EASTERN ARKANSAS REGION
COMPREHENSIVE STUDY

# GRAND PRAIRIE AREA DEMONSTRATION PROJECT

## DRAFT GENERAL REEVALUATION REPORT

## APPENDIX B

## SECTION III - GENERAL ENGINEERING

# SECTION III - GENERAL ENGINEERING

## TABLE OF CONTENTS

# SECTION III - GENERAL ENGINEERING

## PART A - EARTHWORK QUANTITIES AND RIGHTS-OF-WAY

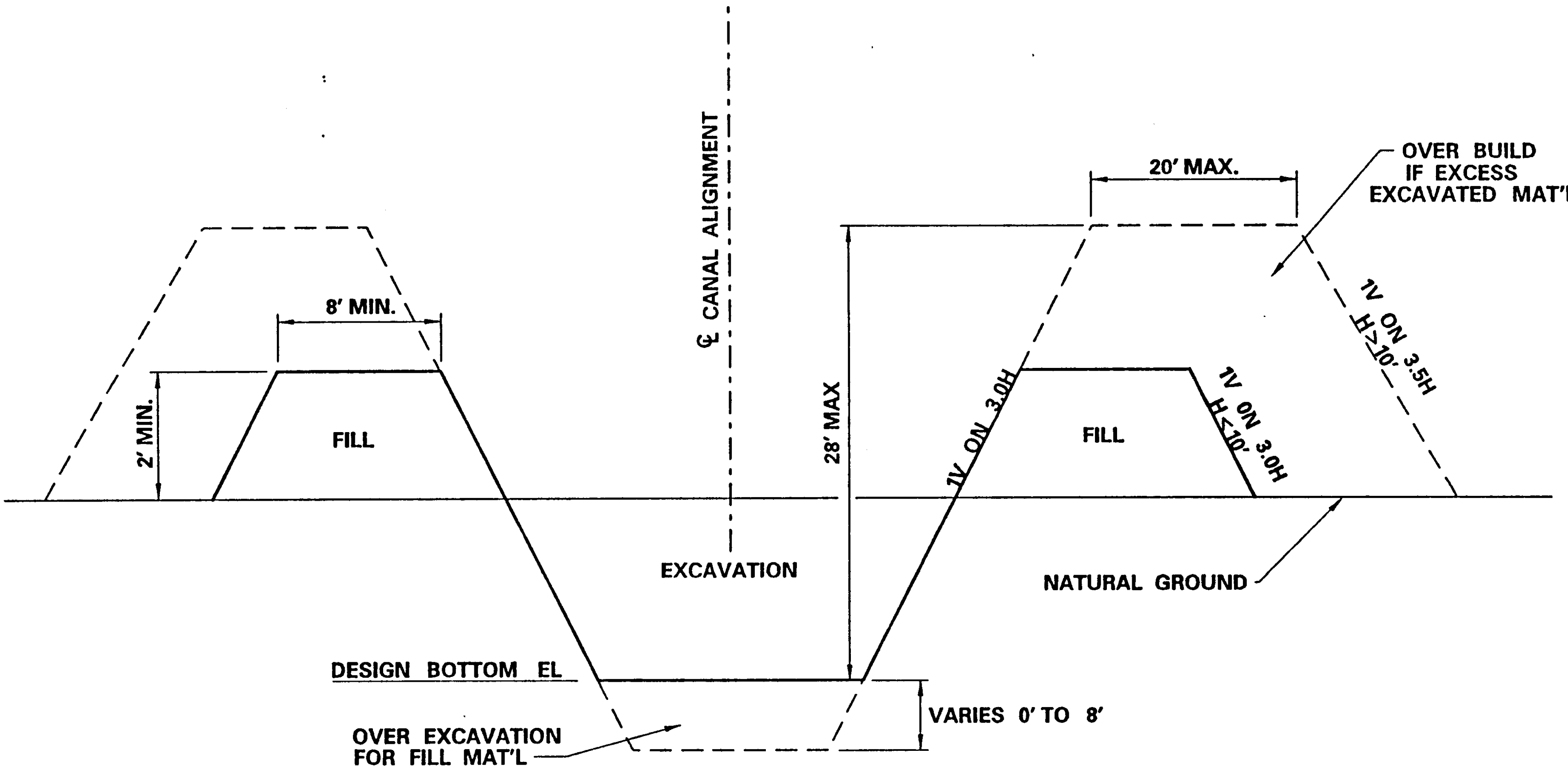
### III-A-01. EARTHWORK QUANTITIES.

Calculations to determine excavation and fill quantities were made utilizing Intergraph Inroads Design Software using data obtained through aerial photography. Topographical Triangulated Networks (ttn's) and Digital Terrain Models (dtm's) were used and templets "pushed" along horizontal and vertical alignments to obtain volumes of cut and fill needed to produce the required minimum canal cross section and levee height. In areas where needed fill was greater than the quantity of cut, vertical offsets were used to provide additional material in order to minimize haul distances and outside borrow areas. Vertical offsets ranged from 1.33' to 8' below the design grade. On selected canals, levee crowns were increased up to 20' wide, levee heights increased by as much as 8' and slopes flattened to 1V on 3.5H to dispose of excess material in reaches where cut exceeded fill. A typical cross section is shown in Plate III-A-1.

Sections were "cut" for mass haul tables and graphs at various intervals. Intervals varied from 100' for short canals up to 2000' for canals eight to twelve miles long. The accuracy of the quantities obtained, as compared to a method more accurate than the end area method, varied with the length of the interval with the more accurate information coming from the shorter intervals. The longer section intervals were used to reduce computer processing time and were justified by the accuracy of the design models used to produce the data. Riprap quantities were computed for siphons, turnouts, weirs, wasteways, and check structures and were based on hydraulic design criteria. Riprap and earthwork quantities are presented in Section VI - Cost Engineering.

### III-A-02. RIGHTS-OF-WAY.

The landside toe of levees was used as a basis to calculate acres of right-of-way for the canals and levee structure. An additional ten feet of right-of-way was added beyond the levee toe for construction purposes to arrive at the final acreage required. The right-of-way requirements include any additional lands necessary for the disposal of excess excavated material.




# TYPICAL CROSS SECTION

US Army Corps of Engineers

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

TYPICAL CROSS SECTION

PLATE
III-A-1

## PART B - RELOCATIONS

### III-B-01. GENERAL.

a. Purpose, Extent and Scope. The purpose of the relocations studies included in this General Reevaluation Report is to identify the facilities (used by and serving the public) which will be impacted by the irrigation water supply project, and to estimate the cost of providing for the continuing function of the facilities.

The extent of the relocations required was determined after considering existing conditions; present and contemplated uses by the owners; criteria for relocations; and general project economics evaluated from field investigations, engineering analysis and cost studies.

The scope of work on which the estimated cost of relocations is based was determined from field investigations of all facility sites that will be impacted by the implementation of the project and discussions with utility owners. The work, if implemented, will consist primarily of building bridges across new canals and altering utilities to accommodate the project.

b. Estimates. The estimates for the relocations of all affected facilities were developed by the Memphis District based on the best available unit prices, estimates from utility owners and on cost records for similar relocations in the past. The identification of affected facilities was based on field investigations and contacts with utility owners.

### III-B-02. ROADS.

Bridges will be required at thirty-four crossings to adequately pass the design flows. The bridge designs are based on Arkansas State Highway Standards and meet HS-20 live loadings. The total relocations cost for bridges is $7,541,400. These costs are presented by item in Section VI - Cost Engineering.

### III-B-03. RAILROADS.

No railroad tracks will require alteration.

## III-B-04. UTILITIES.

a. General. The proposed project will affect utilities at 342 locations within the project area. The utilities are primarily overhead electric lines (141), telephone (84), water (75), gas service (23), fiber optic cables (17), and railroad telegraph lines (2).

b. Utility Provisions. The extent of utility alterations necessary to accommodate the project is predicated on providing horizontal and vertical clearance for project construction, operation and maintenance. Utility alterations are necessary where a canal or pipeline crosses a utility. Where canals and pipelines run parallel to the road and utilities, it is assumed that the work will not interfere with the utilities or the road. The facility list and relocations cost estimates for utility alterations are shown in Table III-B-1.

# TABLE III-B-1

## FACILITY TYPES AND COST BY CONSTRUCTION ITEM

| Item Number | Crossing ID | Facility - 1 Description | Facility - 1 Cost ($000) | Facility - 2 Description | Facility - 2 Cost ($000) | Facility - 3 Description | Facility - 3 Cost ($000) | Facility - 4 Description | Facility - 4 Cost ($000) | Facility - 5 Description | Facility - 5 Cost ($000) | Facility - 6 Description | Facility - 6 Cost ($000) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item 3 | 1000-1 | Underground Telephone | 6 | 7.2 kv Powerline | 12 | | | | | | | | |
| Item 3 | 1000-2 | 115/161 kv Powerline | 33 | | | | | | | | | | |
| Item 3 | 1000-3 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 3 | 1000-4 | 115/161 kv Powerline | 33 | | | | | | | | | | |
| Item 3 | 1500-1 | Underground Telephone | 6 | Gasline | 14 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | |
| Item 3 | 1500-3 | Underground Transcontinental | 70 | Underground Telephone | 6 | | | | | | | | |
| Item 3 | 1500-4 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | |
| Item 3 | 1500-5 | 500 kv Powerline | | | | | | | | | | | |
| Item 3 | 1500-6 | 13.8 kv Powerline | 12 | Waterline | 5 | Underground Telephone | 6 | | | | | | |
| Item 3 | 1520-1 | 13.8 kv Powerline | 12 | Waterline | 5 | Underground Telephone | 6 | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 190 | | 54 | | 29 | | 5 | | 0 | | 0 |
| | | TOTAL FOR ITEM 3 = | 278 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Item 4 | 1000-5 | Gasline | 14 | Fiber Optic Cable | 70 | | | | | | | | |
| Item 4 | 2000-1 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Underground Transcontinental | 70 | | | | | | |
| Item 4 | 2000-1A | | | | | | | | | | | | |
| Item 4 | 2000-2 | | | | | | | | | | | | |
| Item 4 | 2000-2A | 500 kv Powerline | | | | | | | | | | | |
| Item 4 | 2000-2B | | | | | | | | | | | | |
| Item 4 | 2000-3 | | | | | | | | | | | | |
| Item 4 | 2000-3A | 500 kv Powerline | 200 | | | | | | | | | | |
| Item 4 | 2000-4 | Fiber Optic Cable | 70 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Waterline | 5 | | |
| Item 4 | 2000-5 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 4 | 2000-6 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Underground Transcontinental | 70 | | | | | | |
| Item 4 | 2000-7 | | | | | | | | | | | | |
| Item 4 | 2400-1 | | | | | | | | | | | | |
| Item 4 | 2500-1 | Fiber Optic Cable | 70 | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 4 | 2500-1A | 115/161 kv Powerline | | | | | | | | | | | |
| Item 4 | 3000-1 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | | | |
| Item 4 | 3000-2 | Underground Telephone | 6 | Waterline | 5 | | | | | | | | |
| Item 4 | 3200-1A | 115/161 kv Powerline | | | | | | | | | | | |
| Item 4 | 3300-1 | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 408 | | 111 | | 152 | | 6 | | 5 | | 0 |
| | | TOTAL FOR ITEM 4 = | 682 | | | | | | | | | | |

# TABLE III-B-1

## FACILITY TYPES AND COST BY CONSTRUCTION ITEM

| Item Number | Crossing ID | Facility - 1 | | Facility - 2 | | Facility - 3 | | Facility - 4 | | Facility - 5 | | Facility - 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) |
| Item 5A | 2200-1 | | | | | | | | | | | | |
| Item 5A | 2200-10 | Waterline | 5 | | | | | | | | | | |
| Item 5A | 2200-11 | | | | | | | | | | | | |
| Item 5A | 2200-12 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Waterline | 5 | | | | | | |
| Item 5A | 2200-14 | | | | | | | | | | | | |
| Item 5A | 2200-15 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 5A | 2200-16 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 5A | 2200-18 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | |
| Item 5A | 2200-19 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 5A | 2200-4 | Overhead Telephone | 6 | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 5A | 2200-5 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 5A | 2200-6 | 13.8 kv Powerline | 12 | Waterline | 5 | Underground Telephone | 6 | | | | | | |
| Item 5A | 2200-8 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 5A | 2230-2 | | | | | | | | | | | | |
| Item 5A | 2230-3 | | | | | | | | | | | | |
| Item 5A | 2230-4 | | | | | | | | | | | | |
| Item 5A | 2240-1 | Underground Telephone | 6 | | | | | | | | | | |
| Item 5A | 2240-2 | | | | | | | | | | | | |
| Item 5A | 2400-3B | 500 kv Powerline | | | | | | | | | | | |
| Item 5A | 2400-4 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 119 | | 45 | | 23 | | 6 | | 0 | | 0 |
| | | TOTAL FOR ITEM 5A = | 193 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Item 6 | 3000-10 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 6 | 3000-11 | Waterline | 5 | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 6 | 3000-4 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 6 | 3000-5 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 6 | 3000-6 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | | | |
| Item 6 | 3000-7 | | | | | | | | | | | | |
| Item 6 | 3000-8 | 500 kv Powerline | | | | | | | | | | | |
| Item 6 | 3100-1 | 7.2 kv Powerline | 12 | | | | | | | | | | |
| Item 6 | 3100-2 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 6 | 3100-3 | 500 kv Powerline | | | | | | | | | | | |
| Item 6 | 3300-2 | Underground Telephone | 6 | 7.2 kv Powerline | 12 | Waterline | 5 | | | | | | |
| Item 6 | 3300-3 | 13.8 kv Powerline | 12 | | | | | | | | | | |

## TABLE III-B-1

## FACILITY TYPES AND COST BY CONSTRUCTION ITEM

| Item Number | Crossing ID | Facility - 1 | | Facility - 2 | | Facility - 3 | | Facility - 4 | | Facility - 5 | | Facility - 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) |
| Item 6 | 3400-1 | Waterline | 5 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | |
| Item 6 | 3400-2 | | | | | | | | | | | | |
| Item 6 | 3400-3 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 106 | | 64 | | 11 | | 0 | | 0 | | 0 |
| | | TOTAL FOR ITEM 6 = | 181 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Item 7 | 3200-1 | Gasline | 14 | Fiber Optic Cable | 70 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Waterline | 5 | | |
| Item 7 | 3200-10 | 13.8 kv Powerline | 12 | Overhead Telephone | 6 | | | | | | | | |
| Item 7 | 3200-11 | | | | | | | | | | | | |
| Item 7 | 3200-1B | Underground Transmission | 70 | | | | | | | | | | |
| Item 7 | 3200-4 | | | | | | | | | | | | |
| Item 7 | 3200-4A | | | | | | | | | | | | |
| Item 7 | 3200-5 | 7.2 kv Powerline | 12 | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 7 | 3200-6 | Waterline | 5 | | | | | | | | | | |
| Item 7 | 3200-7 | | | | | | | | | | | | |
| Item 7 | 3200-8 | | | | | | | | | | | | |
| Item 7 | 3200-9 | Waterline | 5 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | |
| Item 7 | 3220-1 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 7 | 3220-1A | Waterline | 5 | | | | | | | | | | |
| Item 7 | 3220-1B | Waterline | 5 | | | | | | | | | | |
| Item 7 | 3220-2 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 7 | 3220-3 | | | | | | | | | | | | |
| Item 7 | 3250-1 | Gasline | 14 | Waterline | 5 | 13.8 kv Powerline | 12 | | | | | | |
| Item 7 | 3250-1A | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 160 | | 122 | | 30 | | 6 | | 5 | | 0 |
| | | TOTAL FOR ITEM 7 = | 323 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Item 8 | 3500-1 | | | | | | | | | | | | |
| Item 8 | 3500-3 | | | | | | | | | | | | |
| Item 8 | 3500-4 | | | | | | | | | | | | |
| Item 8 | 3500-5 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 8 | 3500-6 | 13.8 kv Powerline | 12 | Overhead Telephone | 6 | | | | | | | | |
| Item 8 | 3500A-1 | Waterline | 5 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | |

## TABLE III-B-1

## FACILITY TYPES AND COST BY CONSTRUCTION ITEM

| Item Number | Crossing ID | Facility - 1 | | Facility - 2 | | Facility - 3 | | Facility - 4 | | Facility - 5 | | Facility - 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) |
| Item 8 | 3500.02 | Waterline | 5 | | | | | | | | | | |
| Item 8 | 4000-10 | Waterline | 5 | | | | | | | | | | |
| Item 8 | 4000-11 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 8 | 4000-12 | Waterline | 5 | | | | | | | | | | |
| Item 8 | 4000-2 | | | | | | | | | | | | |
| Item 8 | 4000-3 | Underground Telephone | 6 | Waterline | 5 | | | | | | | | |
| Item 8 | 4000-4 | | | | | | | | | | | | |
| Item 8 | 4000-6 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | 7.2 kv Powerline | 12 | | | | | | |
| Item 8 | 4000-7 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 8 | 4000-8 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 8 | 4100-1A | Underground Telephone | 6 | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 8 | 4200-1 | | | | | | | | | | | | |
| Item 8 | 4200-1A | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 104 | | 40 | | 24 | | 12 | | 6 | | 0 |
| | | TOTAL FOR ITEM 8 = | 186 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Item 9 | 4100-1 | | | | | | | | | | | | |
| Item 9 | 4200-2 | Waterline | 5 | | | | | | | | | | |
| Item 9 | 4200-3 | | | | | | | | | | | | |
| Item 9 | 4200-4 | | | | | | | | | | | | |
| Item 9 | 4200-5 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 9 | 4200-6 | | | | | | | | | | | | |
| Item 9 | 4200-7 | | | | | | | | | | | | |
| Item 9 | 4200-8 | | | | | | | | | | | | |
| Item 9 | 4300-1 | Underground Telephone | 6 | Waterline | 5 | | | | | | | | |
| Item 9 | 4400-1 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 9 | 4500-1 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 9 | 4500-3 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 9 | 4510-1 | Underground Telephone | 6 | Waterline | 5 | | | | | | | | |
| Item 9 | 4510-2 | | | | | | | | | | | | |
| Item 9 | 4510-3 | Waterline | 5 | | | | | | | | | | |
| Item 9 | 4510-4 | | | | | | | | | | | | |
| Item 9 | 4520-1 | | | | | | | | | | | | |
| Item 9 | 5000-1 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Waterline | 5 | | | | | | |
| Item 9 | 5000-1A | Underground Telephone | 6 | | | | | | | | | | |

## TABLE III-B-1

## FACILITY TYPES AND COST BY CONSTRUCTION ITEM

| Item Number | Crossing ID | Facility - 1 Description | Facility - 1 Cost ($000) | Facility - 2 Description | Facility - 2 Cost ($000) | Facility - 3 Description | Facility - 3 Cost ($000) | Facility - 4 Description | Facility - 4 Cost ($000) | Facility - 5 Description | Facility - 5 Cost ($000) | Facility - 6 Description | Facility - 6 Cost ($000) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item 9 | 5000-3 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Gasline | 14 | Waterline | 5 | | | | |
| Item 9 | 5000-5 | | | | | | | | | | | | |
| Item 9 | 5000-6A | | | | | | | | | | | | |
| Item 9 | 5200-1 | | | | | | | | | | | | |
| Item 9 | 5200-1A | | | | | | | | | | | | |
| Item 9 | 5200-3 | | | | | | | | | | | | |
| Item 9 | 5200-3A | 7.2 kv Powerline | 12 | | | | | | | | | | |
| Item 9 | 5200-4 | Waterline | 5 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | |
| Item 9 | 5200-5 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 111 | | 75 | | 30 | | 5 | | 0 | | 0 |
| | | TOTAL FOR ITEM 9 = | 221 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Item 10 | 5000-6 | | | | | | | | | | | | |
| Item 10 | 5300-1 | | | | | | | | | | | | |
| Item 10 | 5300-10 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | |
| Item 10 | 5300-11 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Gasline | 14 | | | | | | |
| Item 10 | 5300-11B | 230 kv Powerline | | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 10 | 5300-12 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | | | |
| Item 10 | 5300-13 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 10 | 5300-14 | | | | | | | | | | | | |
| Item 10 | 5300-3 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Overhead Telephone | 6 | Fiber Optic Cable | 70 | Gasline | 14 | Waterline | 5 |
| Item 10 | 5300-4 | | | | | | | | | | | | |
| Item 10 | 5300-5 | 13.8 kv Powerline | 12 | Waterline | 5 | Underground Telephone | 6 | | | | | | |
| Item 10 | 5300-6 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 10 | 5300-7 | | | | | | | | | | | | |
| Item 10 | 5300-8 | Underground Telephone | 6 | Waterline | 5 | 13.8 kv Powerline | 12 | 13.8 kv Powerline | 12 | | | | |
| Item 10 | 5310-3 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | | | |
| Item 10 | 5400-1 | Gasline | 14 | Waterline | 5 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | | | | |
| Item 10 | 5400-2 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 10 | 5400-3 | | | | | | | | | | | | |
| Item 10 | 6400-5 | 115/161 kv Powerline | | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 10 | 6400-6 | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 128 | | 79 | | 56 | | 99 | | 14 | | 5 |
| | | TOTAL FOR ITEM 10 = | 381 | | | | | | | | | | |

## TABLE III-B-1

## FACILITY TYPES AND COST BY CONSTRUCTION ITEM

| Item Number | Crossing ID | Facility - 1 Description | Facility - 1 Cost ($000) | Facility - 2 Description | Facility - 2 Cost ($000) | Facility - 3 Description | Facility - 3 Cost ($000) | Facility - 4 Description | Facility - 4 Cost ($000) | Facility - 5 Description | Facility - 5 Cost ($000) | Facility - 6 Description | Facility - 6 Cost ($000) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item 11 | 5500-1 | Waterline | 5 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | |
| Item 11 | 5500-10 | Underground Telephone | 6 | 7.2 kv Powerline | 12 | 7.2 kv Powerline | 12 | Waterline | 5 | | | | |
| Item 11 | 5500-11 | 7.2 kv Powerline | 12 | | | | | | | | | | |
| Item 11 | 5500-12 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 11 | 5500-13 | 7.2 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 11 | 5500-14 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Waterline | 5 | | | | | | |
| Item 11 | 5500-15 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 11 | 5500-16 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 11 | 5500-1A | Waterline | 5 | | | | | | | | | | |
| Item 11 | 5500-1B | | | | | | | | | | | | |
| Item 11 | 5500-2 | Gasline | 14 | Underground Telephone | 6 | Railroad Telegraph Line | 25 | | | | | | |
| Item 11 | 5500-3 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | | | |
| Item 11 | 5500-4 | 115/161 kv Powerline | 19 | | | | | | | | | | |
| Item 11 | 5500-4A | | | | | | | | | | | | |
| Item 11 | 5500-5 | Underground Telephone | 6 | Waterline | 5 | | | | | | | | |
| Item 11 | 5500-6 | Underground Telephone | 6 | | | | | | | | | | |
| Item 11 | 5500-8 | 7.2 kv Powerline | 12 | Underground Telephone | 6 | Waterline | 5 | | | | | | |
| Item 11 | 5500-9 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Waterline | 5 | | | | | | |
| Item 11 | 6000-1 | Gasline | 14 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | |
| Item 11 | 6000-10 | 115/161 kv Powerline | 16 | Gasline | 14 | | | | | | | | |
| Item 11 | 6000-11 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | Gasline | 84 | Waterline | 5 | | | | |
| Item 11 | 6000-12 | | | | | | | | | | | | |
| Item 11 | 6000-14 | Fiber Optic Cable | 70 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | |
| Item 11 | 6000-2 | 7.2 kv Powerline | 12 | | | | | | | | | | |
| Item 11 | 6000-3 | Underground Telephone | 6 | Underground Telephone | 6 | Railroad Telegraph Line | 25 | | | | | | |
| Item 11 | 6000-4 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 11 | 6000-5 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | | | |
| Item 11 | 6000-5A | Waterline | 5 | | | | | | | | | | |
| Item 11 | 6000-5B | | | | | | | | | | | | |
| Item 11 | 6000-6 | Waterline | 5 | | | | | | | | | | |
| Item 11 | 6000-7 | 115/161 kv Powerline | 17 | | | | | | | | | | |
| Item 11 | 6000-8 | | | | | | | | | | | | |
| Item 11 | 6000-9 | Waterline | 5 | Gasline | 14 | Fiber Optic Cable | 70 | Overhead Telephone | 6 | Underground Telephone | 6 | 13.8 kv Powerline | 12 |
| Item 11 | 6000-9A | | | | | | | | | | | | |
| Item 11 | 6400-1 | Gasline | 84 | | | | | | | | | | |
| Item 11 | 6400-1A | 230 kv Powerline | | | | | | | | | | | |
| Item 11 | 6400-1B | | | | | | | | | | | | |

## TABLE III-B-1

## FACILITY TYPES AND COST BY CONSTRUCTION ITEM

| Item Number | Crossing ID | Facility - 1 Description | Facility - 1 Cost ($000) | Facility - 2 Description | Facility - 2 Cost ($000) | Facility - 3 Description | Facility - 3 Cost ($000) | Facility - 4 Description | Facility - 4 Cost ($000) | Facility - 5 Description | Facility - 5 Cost ($000) | Facility - 6 Description | Facility - 6 Cost ($000) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item 11 | 6400-2 | Fiber Optic Cable | 70 | Underground Telephone | 6 | Waterline | 5 | | | | | | |
| Item 11 | 6400-3 | Underground Telephone | 6 | | | | | | | | | | |
| Item 11 | 6400-4 | 115/161 kv Powerline | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 509 | | 145 | | 259 | | 21 | | 6 | | 12 |
| | | TOTAL FOR ITEM 11 = | 952 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Item 12 | 6000-15 | | | | | | | | | | | | |
| Item 12 | 6000-16 | | | | | | | | | | | | |
| Item 12 | 6000-17 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Waterline | 5 | | | | | | |
| Item 12 | 6000-18 | | | | | | | | | | | | |
| Item 12 | 6000-18B | | | | | | | | | | | | |
| Item 12 | 6000-18C | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 12 | 6000-18D | | | | | | | | | | | | |
| Item 12 | 6000-19 | | | | | | | | | | | | |
| Item 12 | 6000-19B | | | | | | | | | | | | |
| Item 12 | 6000-20 | Fiber Optic Cable | 70 | 13.8 kv Powerline | 12 | Waterline | 5 | Underground Telephone | 6 | | | | |
| Item 12 | 6000-21 | 230 kv Powerline | | | | | | | | | | | |
| Item 12 | 6000-23 | | | | | | | | | | | | |
| Item 12 | 6000-25 | Fiber Optic Cable | 70 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | | | | | | |
| Item 12 | 6000.02 | Gasline | 14 | | | | | | | | | | |
| Item 12 | 6600-10 | 230 kv Powerline | | | | | | | | | | | |
| Item 12 | 6600-11 | 13.8 kv Powerline | 12 | Waterline | 5 | Fiber Optic Cable | 70 | Underground Telephone | 6 | | | | |
| Item 12 | 6600-13 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | |
| Item 12 | 6600-14 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 12 | 6600-17 | | | | | | | | | | | | |
| Item 12 | 6600-4 | | | | | | | | | | | | |
| Item 12 | 6600-5 | | | | | | | | | | | | |
| Item 12 | 6600-7 | Waterline | 5 | | | | | | | | | | |
| Item 12 | 6600-9 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 12 | 6600-9A | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Fiber Optic Cable | 70 | Waterline | 5 | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 237 | | 47 | | 167 | | 17 | | 0 | | 0 |
| | | TOTAL FOR ITEM 12 = | 468 | | | | | | | | | | |

# TABLE III-B-1

## FACILITY TYPES AND COST BY CONSTRUCTION ITEM

| Item Number | Crossing ID | Facility - 1 | | Facility - 2 | | Facility - 3 | | Facility - 4 | | Facility - 5 | | Facility - 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) |
| Item 13 | 6200-1 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | | | | | |
| Item 13 | 6200-10 | Gasline | 84 | | | | | | | | | | |
| Item 13 | 6200-12 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 13 | 6200-13 | | | | | | | | | | | | |
| Item 13 | 6200-14 | | | | | | | | | | | | |
| Item 13 | 6200-17 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Waterline | 5 | | | | | | |
| Item 13 | 6200-18 | | | | | | | | | | | | |
| Item 13 | 6200-18A | 115/161 kv Powerline | | | | | | | | | | | |
| Item 13 | 6200-18B | Gasline | 14 | | | | | | | | | | |
| Item 13 | 6200-19 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | | | | | | | | |
| Item 13 | 6200-20 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 13 | 6200-21 | Gasline | 14 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | | | | | | |
| Item 13 | 6200-22 | Underground Telephone | 6 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Gasline | 14 | Gasline | 14 | Waterline | 5 |
| Item 13 | 6200-26 | 230 kv Powerline | | | | | | | | | | | |
| Item 13 | 6200-27 | | | | | | | | | | | | |
| Item 13 | 6200-28 | | | | | | | | | | | | |
| Item 13 | 6200-29 | 115/161 kv Powerline | | | | | | | | | | | |
| Item 13 | 6200-3 | Underground Telephone | 6 | Waterline | 5 | | | | | | | | |
| Item 13 | 6200-30 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | | | |
| Item 13 | 6200-31 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 13 | 6200-32 | | | | | | | | | | | | |
| Item 13 | 6200-33 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | | | | | | | | |
| Item 13 | 6200-34 | 115/161 kv Powerline | | | | | | | | | | | |
| Item 13 | 6200-35 | 13.8 kv Powerline | 12 | Underground Telephone | 6 | Waterline | 5 | | | | | | |
| Item 13 | 6200-36 | 13.8 kv Powerline | 12 | | | | | | | | | | |
| Item 13 | 6200-4 | | | | | | | | | | | | |
| Item 13 | 6200-6 | | | | | | | | | | | | |
| Item 13 | 6200-7 | | | | | | | | | | | | |
| Item 13 | 6200-9 | Waterline | 5 | | | | | | | | | | |
| Item 13 | 6200.03 | Gasline | 14 | | | | | | | | | | |
| Item 13 | 6200.04 | Gasline | 14 | | | | | | | | | | |
| Item 13 | 6215-1 | Underground Telephone | 6 | Fiber Optic Cable | 70 | 13.8 kv Powerline | 12 | Waterline | 5 | | | | |
| Item 13 | 6216-1 | Gasline | 14 | Waterline | 5 | | | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 291 | | 139 | | 40 | | 19 | | 14 | | 5 |
| | | TOTAL FOR ITEM 13 = | 508 | | | | | | | | | | |
| | | | | | | | | | | | | | |

**TABLE III-B-1**

**FACILITY TYPES AND COST BY CONSTRUCTION ITEM**

| Item Number | Crossing ID | Facility - 1 | | Facility - 2 | | Facility - 3 | | Facility - 4 | | Facility - 5 | | Facility - 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) | Description | Cost ($000) |
| Item 14 | 6215-2 | 7.2 kv Powerline | 12 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | SUBTOTAL | 12 | | | | | | | | | | |
| | | TOTAL FOR ITEM 14 = | 12 | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | TOTAL FOR PROJECT = | 4385 | | | | | | | | | | |

# EASTERN ARKANSAS REGION
# COMPREHENSIVE STUDY

# GRAND PRAIRIE AREA DEMONSTRATION PROJECT

## DRAFT GENERAL REEVALUATION REPORT

## APPENDIX B

## SECTION IV - STRUCTURAL, ELECTRICAL & MECHANICAL

# GRAND PRAIRIE AREA DEMONSTRATION PROJECT
# TABLE OF CONTENTS

## SECTION IV
## STRUCTURAL, ELECTRICAL AND MECHANICAL

## GRAND PRAIRIE AREA DEMONSTRATION PROJECT
## TABLE OF CONTENTS

## SECTION IV
## STRUCTURAL, ELECTRICAL AND MECHANICAL

# SECTION IV - STRUCTURAL, ELECTRICAL & MECHANICAL

## PART A - STRUCTURAL AND MECHANICAL DESIGN DEVELOPEMENT

### 4-A-01. SUPPORT STRUCTURES.

This section presents the basic criteria, assumptions, methods of analysis, and results of the computations for the design of the irrigation structures identified in the Grand Prairie Area Demonstration Project feasibility phase. Sufficient engineering and design was performed to enable refinement of the project features, prepare the baseline cost estimate, develop a design and construction schedule to allow detailed design to begin immediately following receipt of preconstruction engineering and design (PED) funds. The dimensions for the majority of structures were based on historical data of similarly sized structures. The Hydraulics and Hydrology Branch provided itemized spreadsheets of all required structures. The structures included in the spreadsheets were broken into seven structural categories:

1) 100 cfs lift station at Canal 3200.
2) Gated check structures.
3) Gate well structures.
4) Inverted pipe siphons.
5) Inverted box siphons.
6) Bridges.

Typical structural configurations were developed for each structural category. Spreadsheets were then expanded to generate quantities based on hydraulic and site characteristics. Maximum design water depth and operating range were assumed to be 15 feet and three feet respectfully. Actual canal depths will exceed 18 feet where over-excavation has taken place to provide additional fill material. Over excavations have been assumed to take place at locations away from structures. Placing inverts at over excavated elevations rather than design elevations would increase structure lengths and costs.

### 4-A-02. DESIGN CRITERIA.

The Grand Prairie Area Demonstration Project falls outside of the traditional Corps civil works flood control project. The major difference between the Grand Prairie project and a typical flood control project is that controlled amounts of water are being supplied to the system for irrigation use, where as, in a flood control project life and property is being protected from uncontrolled amounts of water. With this in mind, design criteria were obtained from the United States Bureau of Reclamation (USBR) and the Natural Resource Conservation Service (NRCS). NRCS criteria were only looked at briefly and were ruled out for two reasons. The first is our lack of knowledge of their experience with structures of the size and nature that are involved in the Grand Prairie project. The second reason being that the NRCS criteria did not, in our opinion, address problems associated with a project this size. It was evident early on that the USBR criteria showed potential for significant savings in both time and money. This and the long successful history of the USBR in water resource projects like Grand Prairie lead us to pursue their criteria. Several phone conversations and one meeting with USBR have taken place to help gain a better understanding of their criteria. At this point, it was apparent that significant cost savings would be realized, if the USBR criteria were to be used. The major differences between Corps' criteria and USBR criteria was the factor of safety on the precast concrete pipe and that the USBR makes a distinction between a water containing and a water conveying structure. The USBR's water containing structures are designed essentially the same way as a Corps' structure using the hydraulic factor, specified in EM 1110-2-2104. However, the USBR only designs a structure to this higher standard when leakage from a system is critical. Leakage from a system containing earthen canals is not considered critical. Therefore, a system such as the Grand Prairie project is designed using the lesser water conveying criteria. A meeting was then held at the Lower Mississippi Valley Division office between the District, Division and HQUSACE. At this meeting, HQUSACE stated that they saw no reason why USBR criteria could not be used on a Corps' water resources project that is typical of a USBR project as long as it was being interpreted correctly. Applicable USBR criteria can be found in appendices IV-E and IV-F. Quality control and quality assurance correspondence has been included in the "Quality Control Plan and QC/QA Documentation" section. Design Memorandums will be developed as required by ER 1110-2-1150 following approval of this report. The Grand Prairie Area Demonstration Project will be designed in accordance with the criteria and guidance furnished in portions of the USBR standards, Corps of Engineers manuals for engineering and design, industry standards, and other technical references as follows:

1) USBR, Design Standard No.3 - Water Conveyance Systems, Chapter 12 - General Structural Considerations, 1994 (Appendix E).
2) USBR, Standard Specification for Reinforced Concrete Pressure Pipe, M0010000.N91, 01 Nov 91 (Appendix F).
3) US Army Corps of Engineers, Strength Design for Reinforced-Concrete Hydraulic Structures, EM 1110-2-2104.
4) AASHTO, Standard Specifications for Highway Bridges.
5) ACI 318, Building Code Requirements for Reinforced Concrete.
6) AISC, Manual of Steel Construction - Allowable Stress Design.

## 4-A-03. RELIFT STATION.

A small 100-cfs pumping station will be required in Canal 3200 in order to lift the water to a higher elevation for continuous gravity flow through the system. This pumping station will contain five 24" drop-in Flyght pumps, each having a 50 horsepower submersible motor. Pumps will place water into an upper chamber that will then spill over a fixed weir. The weir will prevent backward flow through the pumps whenever the pumps are not running. Conceptual designs were completed for a 100 cfs lift station shown in plates IV-A-03-1 thru IV-A-03-3. U.S. Army Corps of Engineer design criteria (EM 1110-2-2104) was applied to simple beam moments and shears in order to size structural members. Once structural members were sized, a MicroStation 3D model was developed. The 3D model was used to calculate quantities and the center of gravity of the structures. The site work for the 100-cfs pumping station was considered to be negligible.

## 4-A-04. CHECK STRUCTURES.

The main canal has four check structures controlling pool elevations and passing water downstream, see appendix IV-B for sketches. Three of these structures have three gates, 14 feet wide and 13.5 feet high, with an operating range of one foot. The fourth structure has one gate the same size as the three gated structures. There are a total of 10 gates in the four structures. Off-the-shelf roller gates will be used. The structures were designed to flow over the wing walls. At an elevation of 1 foot below the top of the gates, water will begin to flow over the wing walls. The operating head on these gates is anticipated to be approximately four feet. The check structures were sized using the Big Lake Diversion Channel Control Structure as an equivalent structure. The Big Lake structure consists of three gates, 20 feet wide and 15 feet high, side-by-side. The components of the check structures were arranged to meet the needs of this project; however, component sizes similar to those in the Big Lake structure were maintained. Center of gravity and structural quantities were determined using a 3D MicroStation model.

## 4-A-05. GATE WELL STRUCTURES.

This section covers main canal turnouts, lateral canal turnouts, wasteways and conduit check structures, see appendix IV-C for additional information. The main canals have 14 gated conduit check structures controlling pool elevation and passing water downstream. Main lateral canals have 63 pump type turnouts that pump water from one canal to another. These structures consist of one 6x6 gate well and pump. There are 32 gated main canal turnouts, 48 gated lateral turnouts and 7 wasteways for a total of 101 gate well structures. These structures serve different hydraulic functions, but, are structurally identical not including size requirements. All these structures have the same components and general configuration as shown in plates IV-C-I thru IV-C-II. Gate well structures consists of precast concrete flared end sections, a length of precast concrete pipe, a cast-in-place concrete gate well and a gate. The gate wells for these structures range in height from 3.5 feet to 13.5 feet. The required length of pipe was calculated by taking the gate well, height multiplying it by twice the slope, and adding a 10 foot crown width minus a six gate well and two flared end section. Class IV pipe, meeting the requirements of ASTM C361, was used for estimating purposes. A gate well inside dimension transverse to the pipe was assumed to be the pipe diameter plus four feet. The inside longitudinal dimension was set to 6 feet. Wall thickness for the gate wells were assumed to be 10 inches for pipe sizes less than 42 inches, 12 inches otherwise. The gate well base was assumed to be 15 inches thick and extend 8 inches beyond the exterior wall face. An 18 inch thick riprap blanket 35 by 20 feet was assumed on the outlet side.

## 4-A-06. CROSSINGS.

a. General. Several types of crossings are required by this project. The following structures are needed to separate irrigation water from storm water (natural drainage) and vehicle traffic. Separation of irrigation water and storm water is required in order to control the direction of the irrigation water without impeding natural drainage. Water separation has been accomplished through the use of inverted pipe siphons (sag culverts). Vehicle separation or road crossings have been achieved though the use of inverted pipe siphons, inverted box siphons, and bridges. See appendix IV-D for additional information.

b. Inverted Pipe Siphons. This section covers inverted pipe siphons at natural drainage and road crossings. Class III pipe, meeting the requirements of ASTM C361, was used for estimating. A typical profile for a pipe siphon is shown in plate IV-D-1. Fill over the pipe siphons is typically less than 18 feet. Eighteen feet was arrived at by adding three feet of cover to the maximum design channel depth (15 feet). All pipe was assumed to be placed on six inches of bedding material and backfilled with select material to 37 percent of the pipe diameter. Each run of pipe was assumed to have two flared end sections (one at each end) and four precast concrete pipe elbow sections. The elbow sections were used to accomplish the required sag in the profile of the pipe. There are a total of 90 inverted pipe siphons at which the natural drainage was taken under the canals. The length of pipe required to pass natural drainage under a canal was determined by taking cross-sections at the upper end of each canal and measuring the distance from the outside embankment toe to outside embankment toe. Canals where taken under the natural drainage at 13 locations, requiring an assumed length of 300 feet. Three hundred feet was arrived at by taking the larger of the lengths of the pipe required to pass natural drainage under a canal. There are a total of 131 inverted pipe siphon locations. The length of these siphons was determined by taking twice the distance from the inside canal toe to the outside toe of the canal embankment and adding 110 feet to it. The 110 feet represented a 30 foot roadway, two 5 foot ditches with 1V:3H side slopes and two 10 foot berms.

c. Inverted Box Siphons. Twenty five inverted box siphons were identified. A typical profile for a box siphon is shown in plate IV-D-2. These culverts were assumed to be cast-in-place. The box siphons occurred only at road crossings. The same methodology used above to calculate the lengths of pipe siphon at road crossings was used for the box siphons. Wall and slab thicknesses were calculated by adding two inches to the box width. For example, a box with an 8-foot width has 10-inch walls and slabs. This methodology was developed after investigating Arkansas State Highway Department standards and ASTM C789-90 specifications. Table 1 of ASTM C789 is for an HS20 live loading with a soil weight of 120 pcf.

d. Bridges. Thirty-four bridges were identified. Bridge lengths were determined by measuring the distance from top bank to top bank of the canal section mentioned above. Five percent was then added to the measured distance to account for an assumed 15 percent skew. The final length of a bridge was determined by the total length of the nearest combination of 19 feet, 25 feet and 31 feet spans. The three span lengths represent standard precast span lengths developed by the Arkansas Highway Department. The standard precast spans were designed for an HS 20 live loading. Bridges were assumed to have a 24-foot 6-inch clear roadway (see plate IV-D-3).

# Grand Prairie Area Demonstration Project
## Structural, Electrical & Mechanical

# APPENDIX IV-A

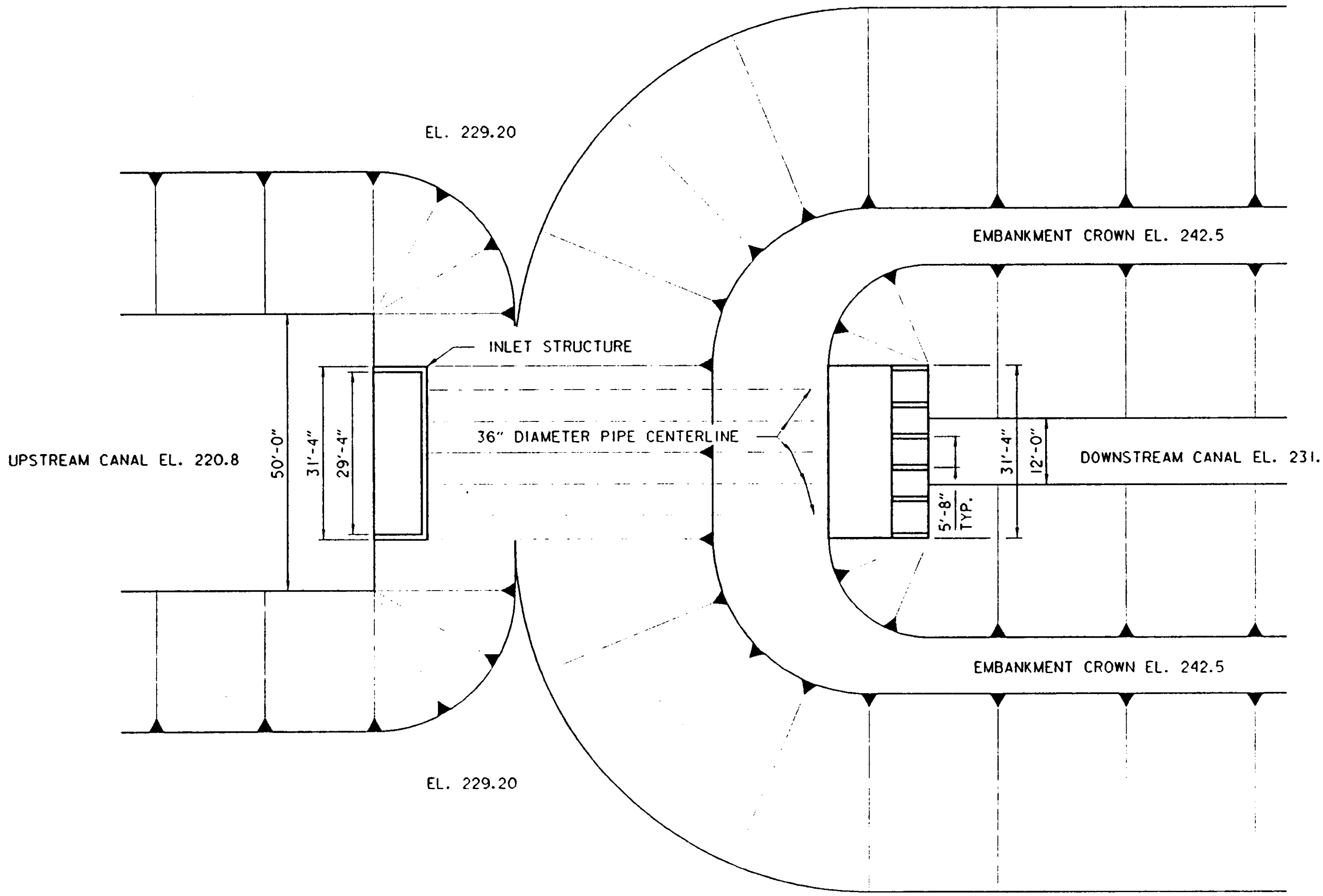
# RELIFT STATION

U.S. Army Corps of Engineers
Memphis District

US Army Corps of Engineers

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT
RELIFT STATION
SITE PLAN




**SITE PLAN**
SCALE 1" = 30'-0"

PLATE
IV-A-1

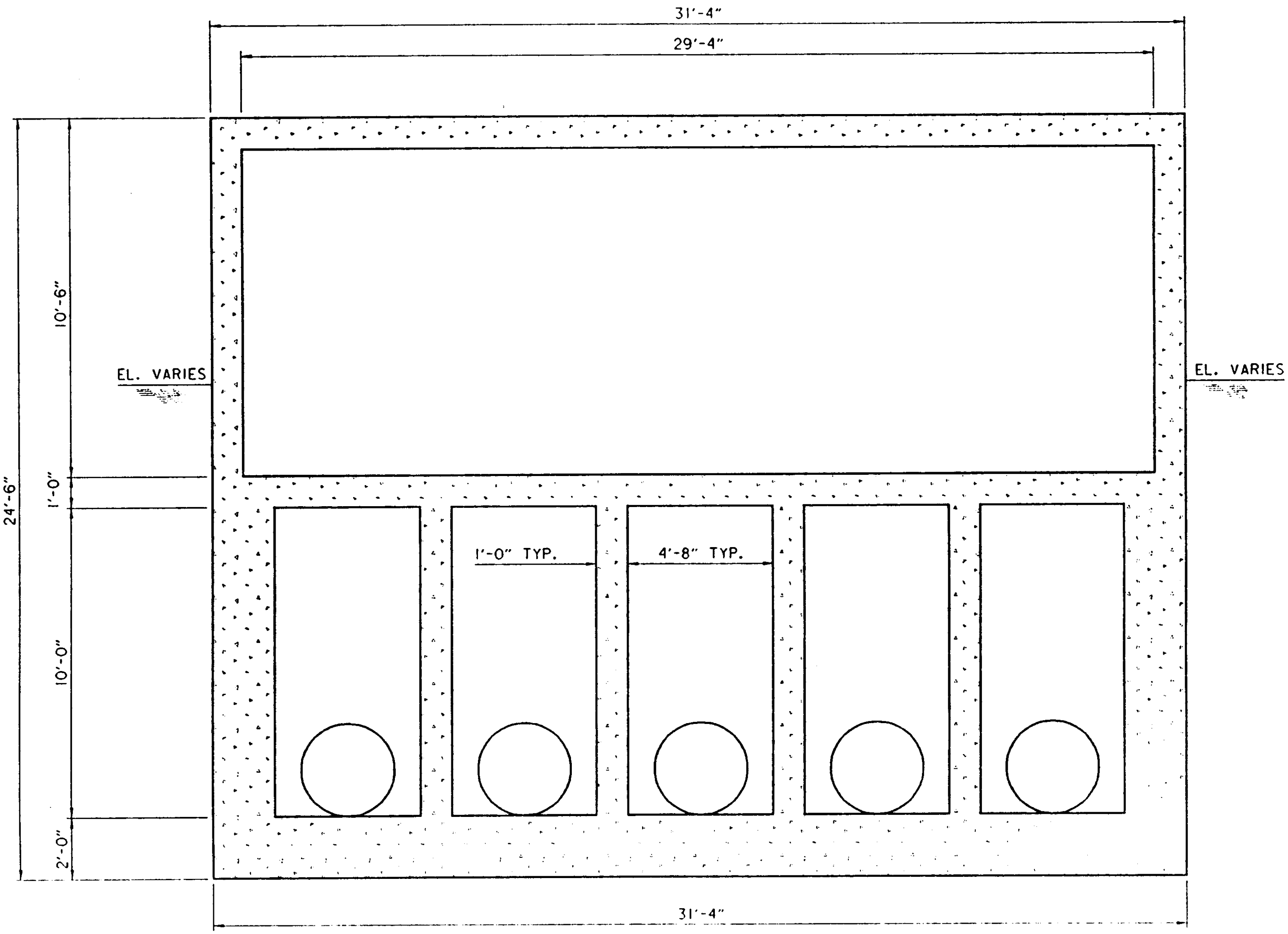
US Army Corps of Engineers

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

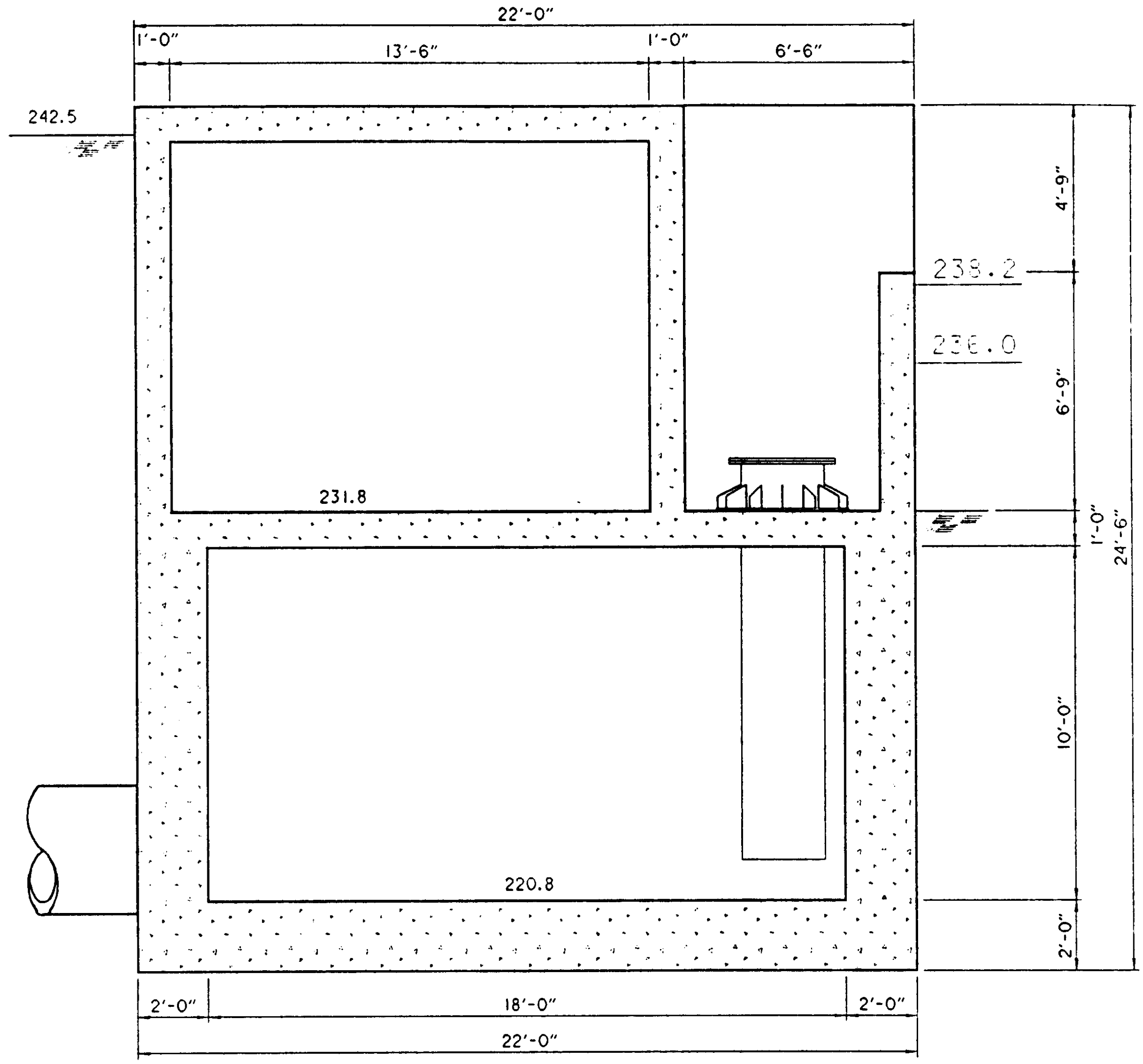
EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

**RELIFT STATION**
**TRANSVERSE SECTION**

PLATE
IV-A-II




**TRANSVERSE SECTION**
SCALE 3/16" = 1'-0"




## LONGITUDINAL SECTION

SCALE 3/16" = 1'-0"

Basic Data

| | |
|---|---|
| Sump Floor | El. 220.8 NGVD |
| Minumum Water Level in Sump | El. 226.2 NGVD |
| Maximum Water Level in Sump | El. 228.0 NGVD |
| Minimum Water Level in Discharge Channel | El. 235.9 NGVD |
| Maximum Water Level in Discharge Channel | El. 238.2 NGVD |
| Elevation of Wier | El. 238.2 NGVD |
| Elevation of Water Flowing Over Wier | El. 241.2 NGVD |
| Maximum Differential Head on Pump (241.2-226.2) | 15 feet |
| Design Station Flow Rate | 100 CFS |
| Design Pump Flow Rate | 20 CFS |

US Army Corps of Engineers

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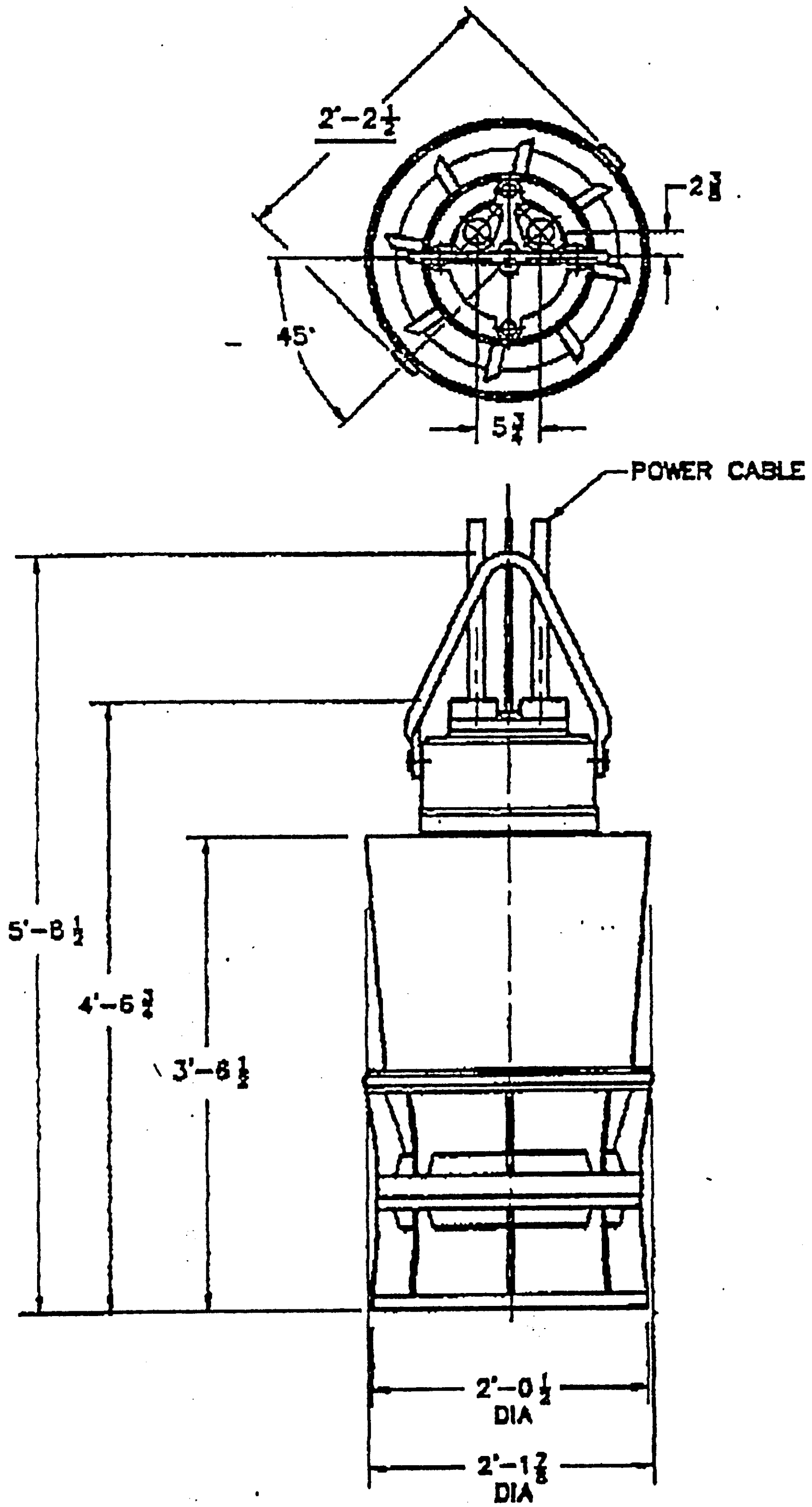
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT
RELIFT STATION
LONGITUDINAL SECTION

PLATE
IV-A-III




| DRIVE UNIT | MOTOR TYPE | WEIGHT (LBS) |
|---|---|---|
| 680 | 35-24-XX | 1700 |
| 880 | 35-28-XX | 1770 |

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MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT
RELIFT STATION
PUMP

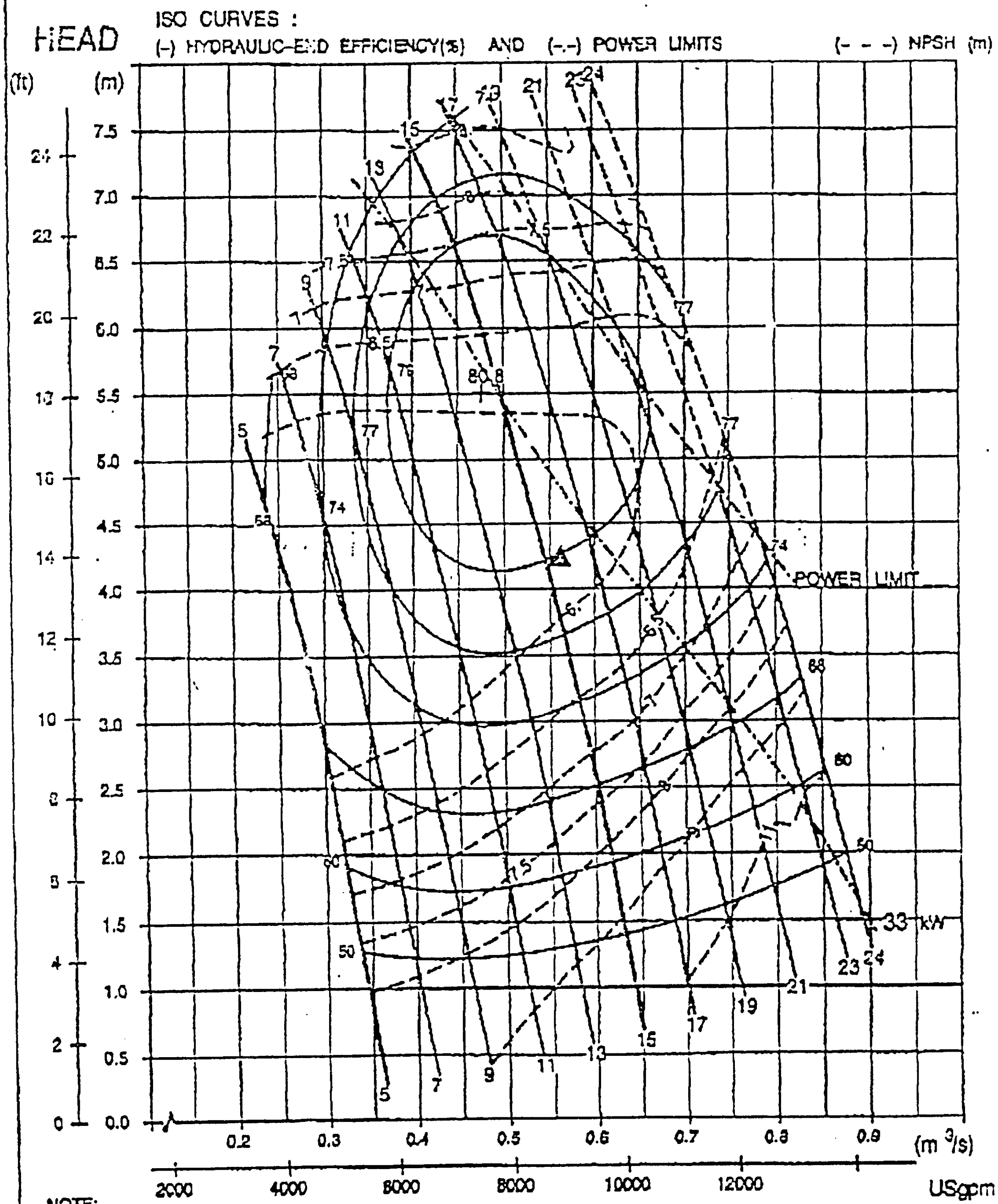
PLATE
IV-A-IV

# PERFORMANCE FIELD

PROD. P 7050

| IMPELLER/HUB DIAMETER | TYPE OF BLADES | NO. OF BLADES | AVAILABLE BLADE ANGLES |
|---|---|---|---|
| 480/260 mm | B | 4 | EVERY DEG FROM 5 TO 24 DEG |

| DRIVE UNIT | MOTOR | POLES | RATED(SHAFT) POWER | GEARTYPE | GEAR RATIO | GEAR EFFICIENCY |
|---|---|---|---|---|---|---|
| 680 | 35-24-8AA | 8 | 33 kW | | | |
| 680 | 35-28-8AA | 8 | 45 | | | |




NOTE:
CURVES ARE BASED ON NOMINAL CONSTANT HYDRAULIC-END SPEED
AND SHOW PERFORMANCE WITH CLEAR WATER.
ALL HYDRAULIC LOSSES UP TO 500 MM. ABOVE THE PUMP/MOTOR TOP ARE INCLUDED

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EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT
**RELIFT STATION**
**PUMP CURVE**

**PLATE**
**IV-A-V**

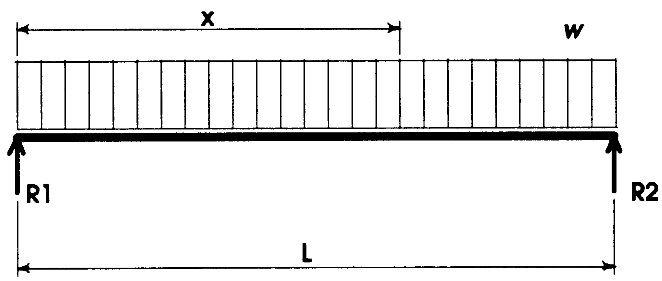
PROJECT: Grand Prairie Demostration Project
Eastern Arkansas

DESIGNED BY: Mike Watson

CHECKED BY: WET

SUBJECT: Relift Station (100 CFS)

**Load Case 1. Simple Beam Uniformly Loaded with Concentrated Load at Center of Span**
**Control Room Floor**




Uniform Load Diagram

**Defined Units:**

$kip := 1000 \cdot lbf$ $\quad ksi := \frac{kip}{in^2}$ $\quad ksi \equiv 1000 \cdot psi$ $\quad kcf := \frac{kip}{ft^2}$

**Input Variables**

**Span lengths:**

| | |
|---|---|
| Simple span length | $L := 5.7 \cdot ft$ |
| **Concrete properties:** | |
| Design compressive strength of concrete: | $f_c := 4 \cdot ksi$ |
| Unit weight of concrete: | $\gamma_c := 0.145 \cdot kcf$ |
| Weight of reinforced concrete: | $\gamma_{rc} := 0.150 \cdot kcf$ |
| **Steel properties:** | |
| Specified yield strength of reinforcement: | $f_y := 60 \cdot ksi$ |
| Steel modulus of elasticity: | $E_s := 29000 \cdot ksi$ |
| **Load Factors:** | |
| Live load: | $LL := 1.7$ |
| Dead load: | $DL := 1.4$ |
| Hydraulic: | $H_f := 1.3$ |

**PROJECT: Grand Prairie Demostration Project**
**Eastern Arkansas**

**DESIGNED BY: Mike Watson**

**CHECKED BY: WET**

**SUBJECT: Relift Station (100 CFS)**

**Uniform Load Analysis:**

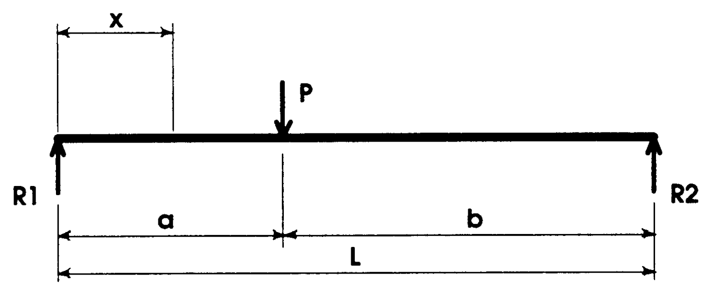
| | | |
|---|---|---|
| Slab thickness: | $T := 12 \cdot in$ | |
| Uniform live load: | $w_L := 100 \cdot \frac{lbf}{ft}$ | $w_L = 0.100 \cdot \frac{kip}{ft}$ |
| Uniform dead load: | $w_D := T \cdot \gamma_{rc}$ | $w_D = 0.150 \cdot \frac{kip}{ft}$ |
| Total factored uniform load: | $w := H_f \cdot \left(DL \cdot w_D + LL \cdot w_L\right)$ | $w = 0.494 \cdot \frac{kip}{ft}$ |
| Reaction at point 1: | $R1 := \frac{w \cdot L}{2}$ | $R1 = 1.41 \cdot kip$ |
| Reaction at point 2: | $R2 := R1$ | $R2 = 1.41 \cdot kip$ |
| Factored moment at x: | $M_w(x) := R1 \cdot x - \frac{w \cdot x^2}{2}$ | |
| Factored shear at x: | $V_w(x) := R1 - w \cdot x$ | |

Determine zero shear location:

| | | |
|---|---|---|
| $x := 0 \cdot ft$ | $x_o := root\left(V_w(x), x\right)$ | $x_o = 2.9 \cdot ft$ |

Maximum positive moment produced coincides with zero shear:

$$M_{pos} := M_w\left(x_o\right) \qquad M_{pos} = 2.0 \cdot kip \cdot ft$$




Concentrated Load Diagram

**Concentrated Load Analysis:**

Note: Assumed narrowest pump dimension is 24". Calculate concentrated load (P) to apply to a one foot strip of the floor slab by dividing the weight of a single pump (2 kips) by 24".

Pump Weight: $P_{pump} := 2 \cdot kip$

Factored Concentrated Load: $P := \left(H_f \cdot LL \cdot \frac{P_{pump}}{24 \cdot in}\right) \cdot 12 \cdot in$ $\qquad P = 2.210 \cdot kip$

Concentrated Load Location: $a := \frac{L}{2}$ $\qquad a = 2.9 \cdot ft$

$b := L - a$ $\qquad b = 2.9 \cdot ft$

Reaction at point 1: $R1 := \frac{P \cdot b}{L}$ $\qquad R1 = 1.11 \cdot kip$

Reaction at point 2: $R2 := \frac{P \cdot a}{L}$ $\qquad R2 = 1.11 \cdot kip$

Moment at x<a: $M_a(x) := R1 \cdot x$

Moment at x>a: $M_b(x) := (R1 \cdot x) - P \cdot (x - a)$

Moment at x: $M_p(x) := if\left(x<a, M_a(x), M_b(x)\right)$

Factored shear at x: $V_p(x) := if(x<a, R1, -R2)$

Maximum positive moments coincides with the concentrated load:

$M_{pos} := M_p(a)$ $\qquad M_{pos} = 3.1 \cdot kip \cdot ft$

PROJECT: Grand Prairie Demostration Project
Eastern Arkansas

DESIGNED BY: Mike Watson

CHECKED BY: WET

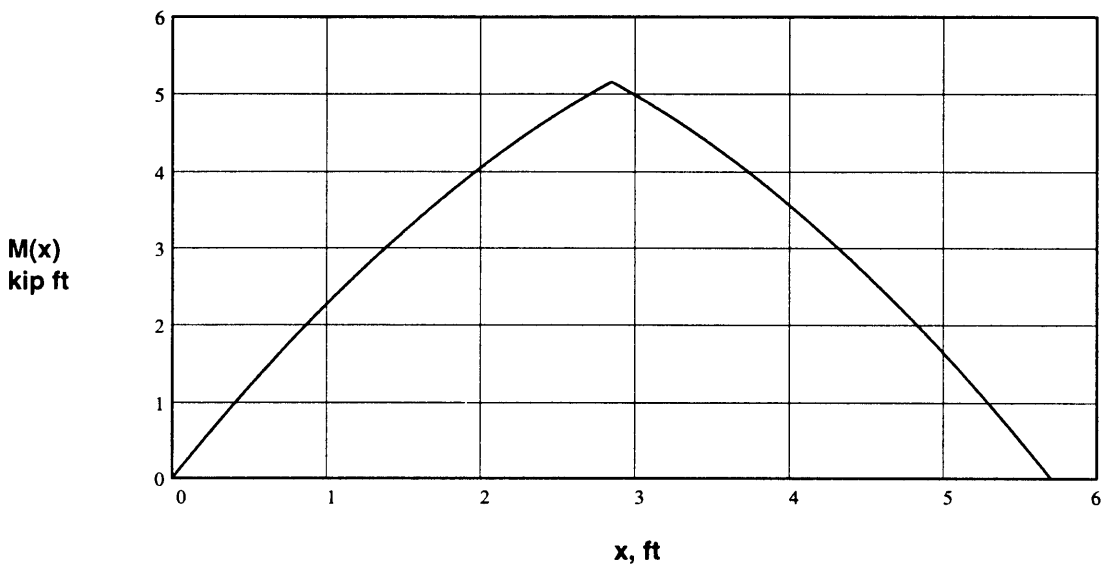
SUBJECT: Relift Station (100 CFS)

## Superimposed Shear and Moment Diagrams

### Plot of moment M(x) versus x for N points across the span

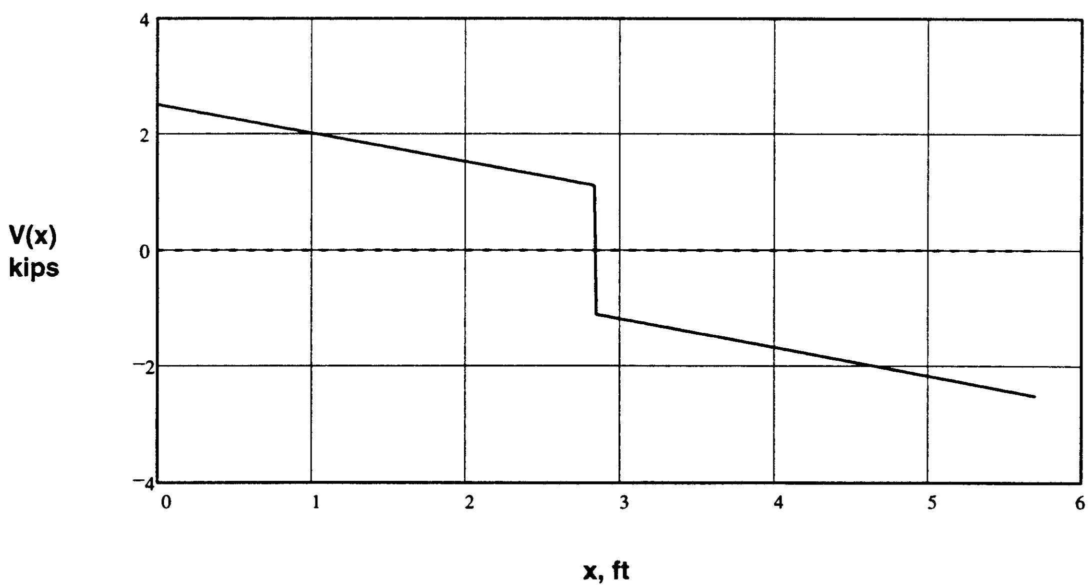
$N := 2000$ $\qquad M(x) := M_w(x) + M_p(x)$ $\qquad M_{max} := M\left(\frac{L}{2}\right)$

$x := 0 \cdot ft, \frac{L}{N} .. L$ $\qquad M_{max} = 5.156 \cdot kip \cdot ft$




### Plot of shear V(x) versus x for N points across the beam

$V(x) := V_w(x) + V_p(x)$



COMPUTATION SHEET

PROJECT: Grand Prairie Demostration Project
Eastern Arkansas

DESIGNED BY: Mike Watson

CHECKED BY: WET

SUBJECT: Relift Station (100 CFS)

**Concrete Design:**

$M_{req} := M_{max}$

Factored moment required: $M_{req} = 5.2 \cdot kip \cdot ft$

Try:

$T = 12.0 \cdot in$ $\quad b := 12 \cdot in$ $\quad Bar := \frac{4}{8} \cdot in$ $\quad cover := 4 \cdot in$ $\quad \phi := 0.9$ ACI Sec. 9.3.2.1

$d := T - cover - \frac{Bar}{2}$ $\quad d = 7.7 \cdot in$ $\quad A_s := \frac{3.1416 \cdot Bar^2}{4}$ $\quad A_s = 0.2 \cdot in^2$

$\beta_1 := if\left[f_c > 8 \cdot ksi, 0.65, if\left[f_c \le 4 \cdot ksi, 0.85, 0.85 - \left(\frac{f_c - 4 \cdot ksi}{1 \cdot ksi}\right) \cdot 0.05\right]\right]$ $\quad \beta_1 = 0.85$ ACI 10.2.7.3

$\rho_b := 0.85 \cdot \beta_1 \cdot \frac{f_c}{f_y} \cdot \left(\frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$ $\quad \rho_{max} := 0.35 \cdot \rho_b$ $\quad \rho_{max} = 0.0100$ ACI 10.3.3 & EM-1110-2-2104, pg 3-4

$\rho_{min} := 0.0018$ ACI 10.5.3 & 7.12

$\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0021$

$M_u := d^2 \cdot b \cdot f_y \cdot \phi \cdot \rho \cdot \left(1 - 0.59 \cdot \frac{f_y \cdot \rho}{f_c}\right) \cdot \frac{12 \cdot in}{b}$ $\quad M_u = 6.7 \cdot kip \cdot ft$

$M_{req} = 5.2 \cdot kip \cdot ft$

$M_u > M_{max}$ OK

Horizontal shear:

$V_{req} := \frac{V(0 \cdot ft)}{H_f}$ $\quad V_{req} = 1.9 \cdot kip$

$b = 12.0 \cdot in$ $\quad d = 7.7 \cdot in$ $\quad \phi := 0.85$ ACI Sec. 9.3.2.3

$V_c := 2 \cdot \sqrt{f_c \cdot psi} \cdot b \cdot d \cdot \frac{12 \cdot in}{b}$ $\quad V_u := \phi \cdot V_c$ $\quad V_u = 10 \cdot kip$ ACI Sec. 14.2.3, 11.10.1, 11.3.1.1, 11.5.5.1

$V_u > V_h$ OK

## Summary

$T = 12.0 \cdot in$ $\quad L = 5.7 \cdot ft$ $\quad P = 2.2 \cdot kip$ $\quad w = 0.494 \cdot \frac{kip}{ft}$

$size := Bar \cdot \frac{8}{in}$ $\quad size = 4$

$spacing := b$ $\quad spacing = 12.0 \cdot in$

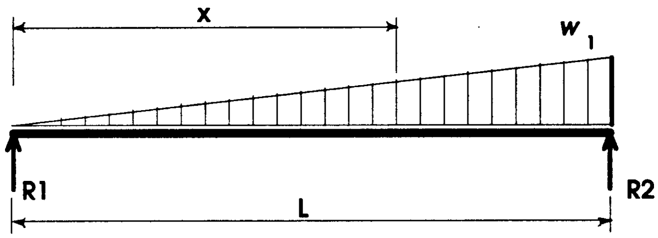
PROJECT: Grand Prairie Demostration Project
Eastern Arkansas

DESIGNED BY: Mike Watson

CHECKED BY: WET

SUBJECT: Relift Station (100 CFS)

**Load Case 2. Simple Beam - Triangular Loading Increasing Uniformly to One End. Control Room Wall on the Inlet Side.**




Triangular Load Diagram

**Defined Units:**

$kip := 1000 \cdot lbf$ $\quad ksi := \frac{kip}{in^2}$ $\quad ksi \equiv 1000 \cdot psi$ $\quad kcf := \frac{kip}{ft^2}$

**Input Variables**

**Unit weights:**

Soil weight: $\gamma_s := 0.125 \cdot kcf$

Water weight: $\gamma_w := 0.0624 \cdot kcf$

**Span lengths:**

Total length: $L := 10.5 \cdot ft$

**Concrete properties:**

Design compressive strength of concrete: $f_c := 4 \cdot ksi$

Unit weight of concrete: $w_c := 0.145 \cdot kcf$

Weight of reinforced concrete: $w_{rc} := 0.150 \cdot kcf$

**Steel properties:**

Specified yield strength of reinforcement: $f_y := 60 \cdot ksi$

Steel modulus of elasticity: $E_s := 29000 \cdot ksi$

**Load Factors:**

Live load: $LL := 1.7$

Dead load: $DL := 1.4$

Hydraulic: $H_f := 1.3$

**Beam Analysis:**

Equivalent fluid pressure: $\gamma_e := \gamma_w + 0.5 \cdot (\gamma_s - \gamma_w)$ $\gamma_e = 0.094 \cdot \text{kcf}$

Uniform load at point 1: $w_1 := L \cdot \gamma_e$ $w_1 = 0.98 \cdot \frac{\text{kip}}{\text{ft}}$

Reaction at point 1: $R1 := \frac{w_1 \cdot L}{6}$ $R1 = 1.72 \cdot \text{kip}$

Reaction at point 2: $R2 := \frac{w_1 \cdot L}{3}$ $R2 = 3.44 \cdot \text{kip}$

Moment at x: $M_{12}(x) := R1 \cdot x - \frac{w_1 \cdot x^3}{6 \cdot L}$

Shear at x: $V_{12}(x) := R1 - w_1 \cdot \frac{(x)^2}{2 \cdot L}$

Determine zero shear location:

$x := L$ $x_o := \text{root}(V_{12}(x), x)$ $x_o = 6.1 \cdot \text{ft}$

Maximum positive moment coincides with zero shear:

$M_{pos} := M_{12}(x_o)$ $M_{pos} = 7.0 \cdot \text{kip} \cdot \text{ft}$

COMPUTATION SHEET

PROJECT: Grand Prairie Demostration Project
Eastern Arkansas

DESIGNED BY: Mike Watson

CHECKED BY: WET

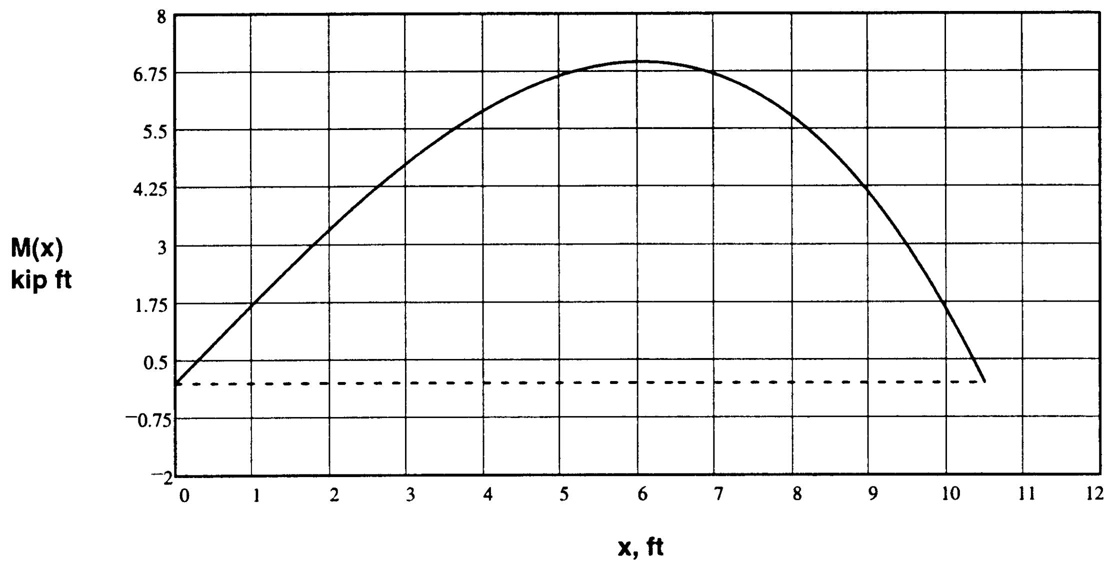
SUBJECT: Relift Station (100 CFS)

**Superimposed Shear and Moment Diagrams**

**Plot of moment M(x) versus x for N points across the span**

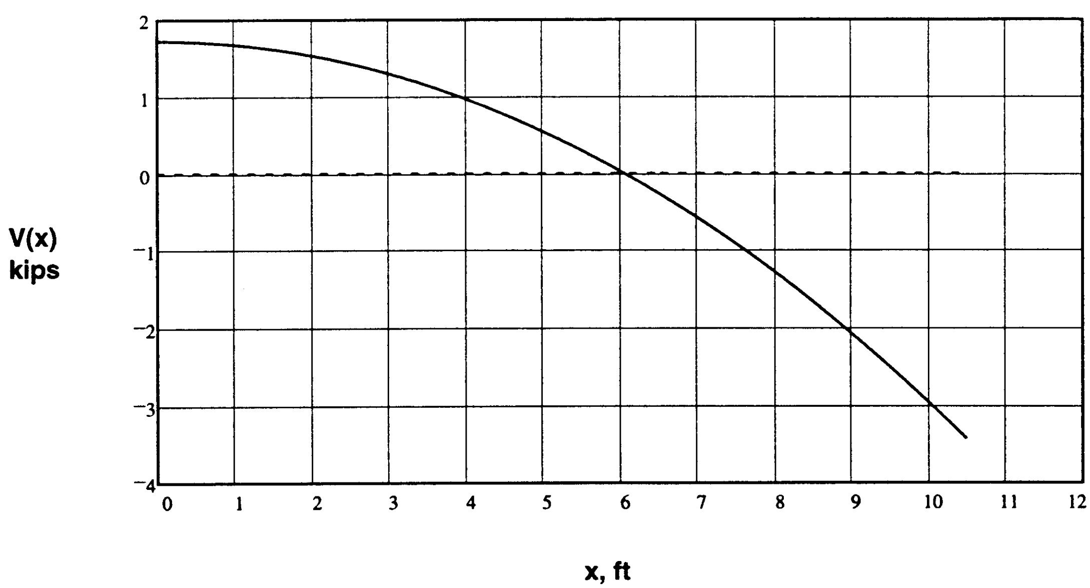
$N := 2000$ $\quad$ $M(x) := M_{12}(x)$ $\quad$ $M_{max} := M(x_o)$

$x := 0 \cdot ft, \frac{L}{N} .. L$ $\quad$ $M_{max} = 6.958 \cdot kip \cdot ft$




**Plot of shear V(x) versus x for N points across the beam**

$V(x) := V_{12}(x)$



**PROJECT: Grand Prairie Demostration Project**
**Eastern Arkansas**

**DESIGNED BY: Mike Watson**

**CHECKED BY: WET**

**SUBJECT: Relift Station (100 CFS)**

**Concrete Design:**

$M_{max} = 7.0 \cdot kip \cdot ft$

Factored moment required: $M_{req} := H_f \cdot LL \cdot M_{max}$ $\qquad M_{req} = 15.4 \cdot kip \cdot ft$

Try:

$T := 12 \cdot in \qquad b := 10 \cdot in \qquad Bar := \frac{5}{8} \cdot in \qquad cover := 1.5 \cdot in \qquad \phi := 0.9$ ACI Sec. 9.3.2.1

$d := T - cover - \frac{Bar}{2} \qquad d = 10.2 \cdot in \qquad A_s := \frac{3.1416 \cdot Bar^2}{4} \qquad A_s = 0.31 \cdot in^2$

$\beta_1 := if\left[f_c > 8 \cdot ksi, 0.65, if\left[f_c < 4 \cdot ksi, 0.85, 0.85 - \left(\frac{f_c - 4 \cdot ksi}{1 \cdot ksi}\right) \cdot 0.05\right]\right] \qquad \beta_1 = 0.8$ ACI 10.2.7.3

$\rho_b := 0.85 \cdot \beta_1 \cdot \frac{f_c}{f_y} \cdot \left(\frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right) \qquad \rho_{max} := 0.35 \cdot \rho_b \qquad \rho_{max} = 0.01$ ACI 10.3.3 & EM-1110-2-2104, pg 3-4

$\rho_{min} := 0.0018$ ACI 10.5.3 & 7.12

$\rho := \frac{A_s}{b \cdot d} \qquad \rho = 0.003$

$M_u := d^2 \cdot b \cdot f_y \cdot \phi \cdot \rho \cdot \left(1 - 0.59 \cdot \frac{f_y \cdot \rho}{f_c}\right) \cdot \frac{12 \cdot in}{b}$ $\qquad M_u = 16.4 \cdot kip \cdot ft$

$M_{req} = 15.4 \cdot kip \cdot ft$

$M_u > M_{max}$ OK

Horizontal shear:

$V_{req} := LL \cdot V(L) \qquad V_{req} = -5.9 \cdot kip$

$b = 10.0 \cdot in \qquad d = 10.2 \cdot in \qquad \phi := 0.85$ ACI Sec. 9.3.2.3

$V_c := 2 \cdot \sqrt{f_c \cdot psi} \cdot b \cdot d \cdot \frac{12 \cdot in}{b} \qquad V_u := \phi \cdot V_c \qquad V_u = 13.1 \cdot kip$ ACI Sec. 11.3.1.1 & 11.5.5.1

$V_u > V_h$ OK

## Summary

Wall thickness: $T = 12.0 \cdot in$

Vertical bars: $size := Bar \cdot \frac{8}{in} \qquad size = 5.0$

$spacing := b \qquad spacing = 10.0 \cdot in$

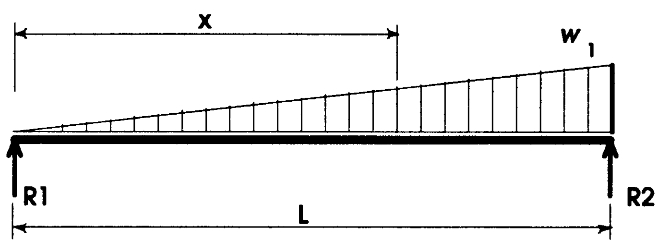
PROJECT: Grand Prairie Demostration Project
Eastern Arkansas

DESIGNED BY: Mike Watson

CHECKED BY: WET

SUBJECT: Relift Station (100 CFS)

**Load Case 3. Simple Beam - Triangular Loading Increasing Uniformly to One End. Lower Pump Bay Side Wall.**




Triangular Load Diagram

**Defined Units:**

$kip := 1000 \cdot lbf$ $\quad ksi := \frac{kip}{in^2}$ $\quad ksi \equiv 1000 \cdot psi$ $\quad kcf := \frac{kip}{ft^2}$

**Input Variables**

**Unit weights:**

Soil weight: $\gamma_s := 0.125 \cdot kcf$

Water weight: $\gamma_w := 0.0624 \cdot kcf$

**Span lengths:**

Total length: $L := 11.5 \cdot ft$

**Concrete properties:**

Design compressive strength of concrete: $f_c := 4 \cdot ksi$

Unit weight of concrete: $w_c := 0.145 \cdot kcf$

Weight of reinforced concrete: $w_{rc} := 0.150 \cdot kcf$

**Steel properties:**

Specified yield strength of reinforcement: $f_y := 60 \cdot ksi$

Steel modulus of elasticity: $E_s := 29000 \cdot ksi$

**Load Factors:**

Live load: $LL := 1.7$

Dead load: $DL := 1.4$

Hydraulic: $H_f := 1.3$

**COMPUTATION SHEET**

**PROJECT: Grand Prairie Demostration Project**
**Eastern Arkansas**

**DESIGNED BY: Mike Watson**

**CHECKED BY: WET**

**SUBJECT: Relift Station (100 CFS)**

**Beam Analysis:**

Equivalent fluid pressure: $\gamma_e := \gamma_w + 0.5 \cdot (\gamma_s - \gamma_w)$ $\gamma_e = 0.094 \cdot \text{kcf}$

Uniform load at point 1: $w_1 := L \cdot \gamma_e$ $w_1 = 1.08 \cdot \frac{\text{kip}}{\text{ft}}$

Reaction at point 1: $R1 := \frac{w_1 \cdot L}{6}$ $R1 = 2.07 \cdot \text{kip}$

Reaction at point 2: $R2 := \frac{w_1 \cdot L}{3}$ $R2 = 4.13 \cdot \text{kip}$

Triangular moment at x: $M_{12}(x) := R1 \cdot x - \frac{w_1 \cdot x^3}{6 \cdot L}$

Triangular shear at x: $V_{12}(x) := R1 - w_1 \cdot \frac{(x)^2}{2 \cdot L}$

Determine zero shear location:

$x := L$ $x_o := \text{root}(V_{12}(x), x)$ $x_o = 6.6 \cdot \text{ft}$

Maximum positive moment coincides with zero shear:

$M_{pos} := M_{12}(x_o)$ $M_{pos} = 9.1 \cdot \text{kip} \cdot \text{ft}$

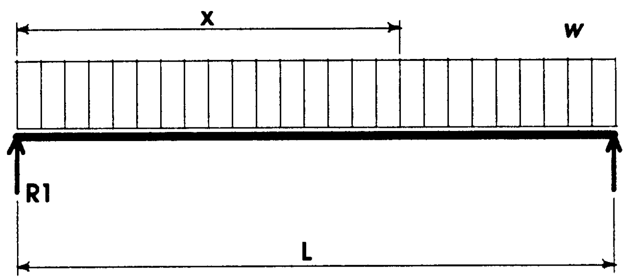
**PROJECT: Grand Prairie Demostration Project**
**Eastern Arkansas**

**DESIGNED BY: Mike Watson**

**CHECKED BY: WET**

**SUBJECT: Relift Station (100 CFS)**

**Load Case 1. Simple Beam - Uniform Surcharge Load.**
**Lower Pump Bay Side Wall.**




**Uniform Load Diagram**

**Uniform Load Analysis:**

| | | |
|---|---|---|
| Uniform surcharge load: | $w := \gamma_e \cdot 10.5 \cdot ft$ | $w = 0.984 \cdot \frac{kip}{ft}$ |
| Reaction at point 1: | $R1 := \frac{w \cdot L}{2}$ | $R1 = 5.66 \cdot kip$ |
| Reaction at point 2: | $R2 := R1$ | $R2 = 5.66 \cdot kip$ |
| Uniform moment at x: | $M_{11}(x) := R1 \cdot x - \frac{w \cdot x^2}{2}$ | |
| Uniform shear at x: | $V_{11}(x) := R1 - w \cdot x$ | |

**Superimposed Shear and Moment Equations:**

Moment at x: $M(x) := M_{12}(x) + M_{11}(x)$

Shear at x: $V(x) := V_{12}(x) + V_{11}(x)$

Determine zero shear location:

$x := 0 \cdot ft$ $\quad x_o := root(V(x), x)$ $\quad x_o = 6.1 \cdot ft$

Maximum positive moment produced coincides with zero shear:

$M_{pos} := M(x_o)$ $\quad M_{pos} = 25.3 \cdot kip \cdot ft$

COMPUTATION SHEET

PROJECT: Grand Prairie Demostration Project
Eastern Arkansas

DESIGNED BY: Mike Watson

CHECKED BY: WET

SUBJECT: Relift Station (100 CFS)

Superimposed Shear and Moment Diagrams

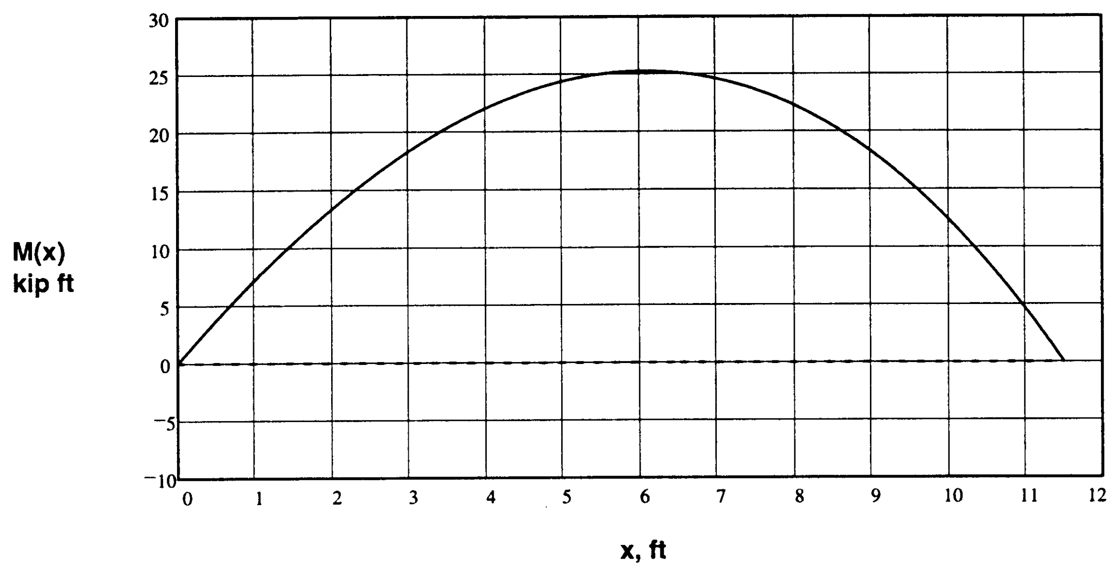
**Plot of moment M(x) versus x for N points across the span**

$N := 2000$

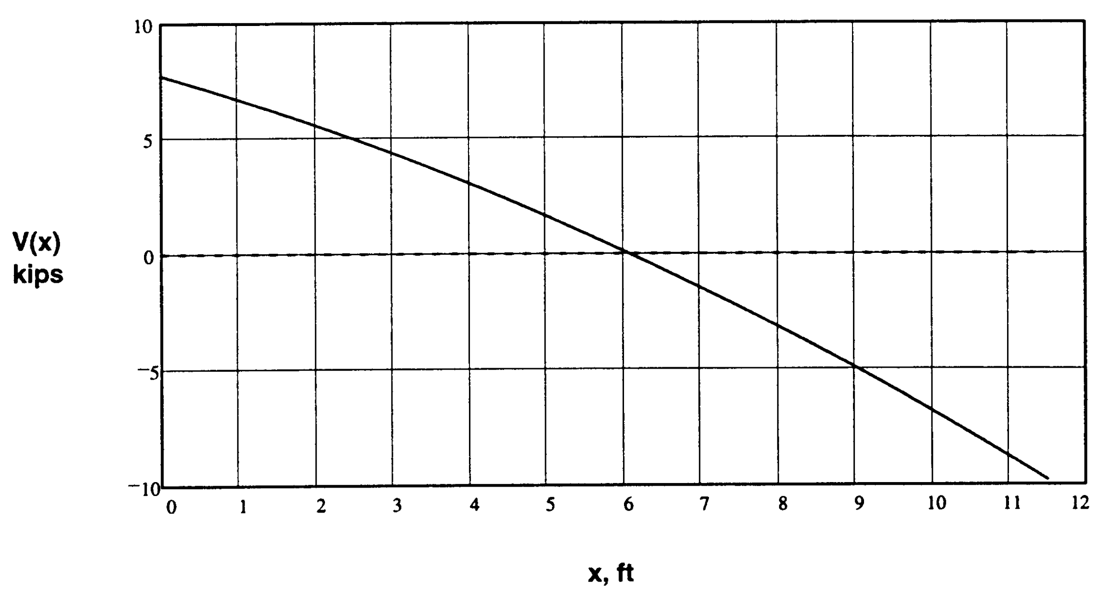
$x := 0 \cdot ft, \frac{L}{N} .. L$

$M_{max} := M(x_o)$

$M_{max} = 25.258 \cdot kip \cdot ft$




**Plot of shear V(x) versus x for N points across the beam**



## COMPUTATION SHEET

PROJECT: Grand Prairie Demostration Project
Eastern Arkansas

DESIGNED BY: Mike Watson

CHECKED BY: WET

SUBJECT: Relift Station (100 CFS)

**Concrete Design:**

$M_{max} = 25.3 \cdot kip \cdot ft$

Factored moment required: $M_{req} := H_f \cdot LL \cdot M_{max}$ $\quad M_{req} = 55.8 \cdot kip \cdot ft$

Try:

$T := 24 \cdot in$ $\quad b := 8 \cdot in$ $\quad Bar := \frac{6}{8} \cdot in$ $\quad cover := 4 \cdot in$ $\quad \phi := 0.9$ ACI Sec. 9.3.2.1

$d := T - cover - \frac{Bar}{2}$ $\quad d = 19.6 \cdot in$ $\quad A_s := \frac{3.1416 \cdot Bar^2}{4}$ $\quad A_s = 0.44 \cdot in^2$

$\beta_1 := if\left[f_c > 8 \cdot ksi, 0.65, if\left[f_c < 4 \cdot ksi, 0.85, 0.85 - \left(\frac{f_c - 4 \cdot ksi}{1 \cdot ksi}\right) \cdot 0.05\right]\right]$ $\quad \beta_1 = 0.8$ ACI 10.2.7.3

$\rho_b := 0.85 \cdot \beta_1 \cdot \frac{f_c}{f_y} \cdot \left(\frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$ $\quad \rho_{max} := 0.35 \cdot \rho_b$ $\quad \rho_{max} = 0.01$ ACI 10.3.3 & EM-1110-2-2104, pg 3-4

$\rho_{min} := 0.0018$ ACI 10.5.3 & 7.12

$\rho := \frac{A_s}{b \cdot d}$ $\quad \rho = 0.0028$

$M_u := d^2 \cdot b \cdot f_y \cdot \phi \cdot \rho \cdot \left(1 - 0.59 \cdot \frac{f_y \cdot \rho}{f_c}\right) \cdot \frac{12 \cdot in}{b}$ $\quad M_u = 57.1 \cdot kip \cdot ft$

$M_{req} = 55.8 \cdot kip \cdot ft$

$M_u > M_{max}$ OK

Horizontal shear:

$V_{req} := LL \cdot V(L)$ $\quad V_{req} = -16.6 \cdot kip$

$b = 8.0 \cdot in$ $\quad d = 19.6 \cdot in$ $\quad \phi := 0.85$ ACI Sec. 9.3.2.3

$V_c := 2 \cdot \sqrt{f_c \cdot psi} \cdot b \cdot d \cdot \frac{12 \cdot in}{b}$ $\quad V_u := \phi \cdot V_c$ $\quad V_u = 25.3 \cdot kip$ ACI Sec. 11.3.1.1 & 11.5.5.1

$V_u > V_h$ OK

## Summary

Wall thickness: $T = 24.0 \cdot in$

Vertical bars: $size := Bar \cdot \frac{8}{in}$ $\quad size = 6.0$

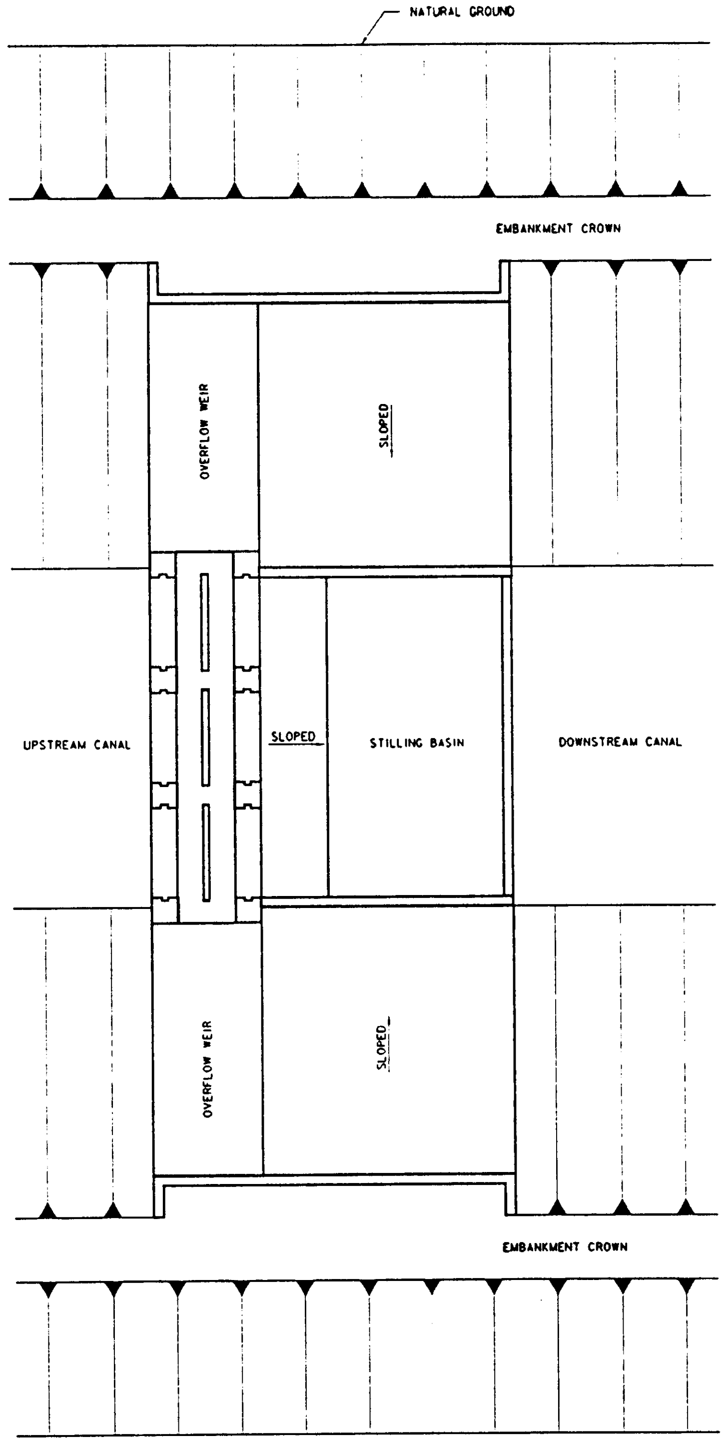
$spacing := b$ $\quad spacing = 8.0 \cdot in$

# Grand Prairie Area Demonstration Project
## Structural, Electrical & Mechanical

# APPENDIX IV-B

# CHECK STRUCTURES

U.S. Army Corps of Engineers
Memphis District




**TYPICAL SITE LAYOUT**
N.T.S.

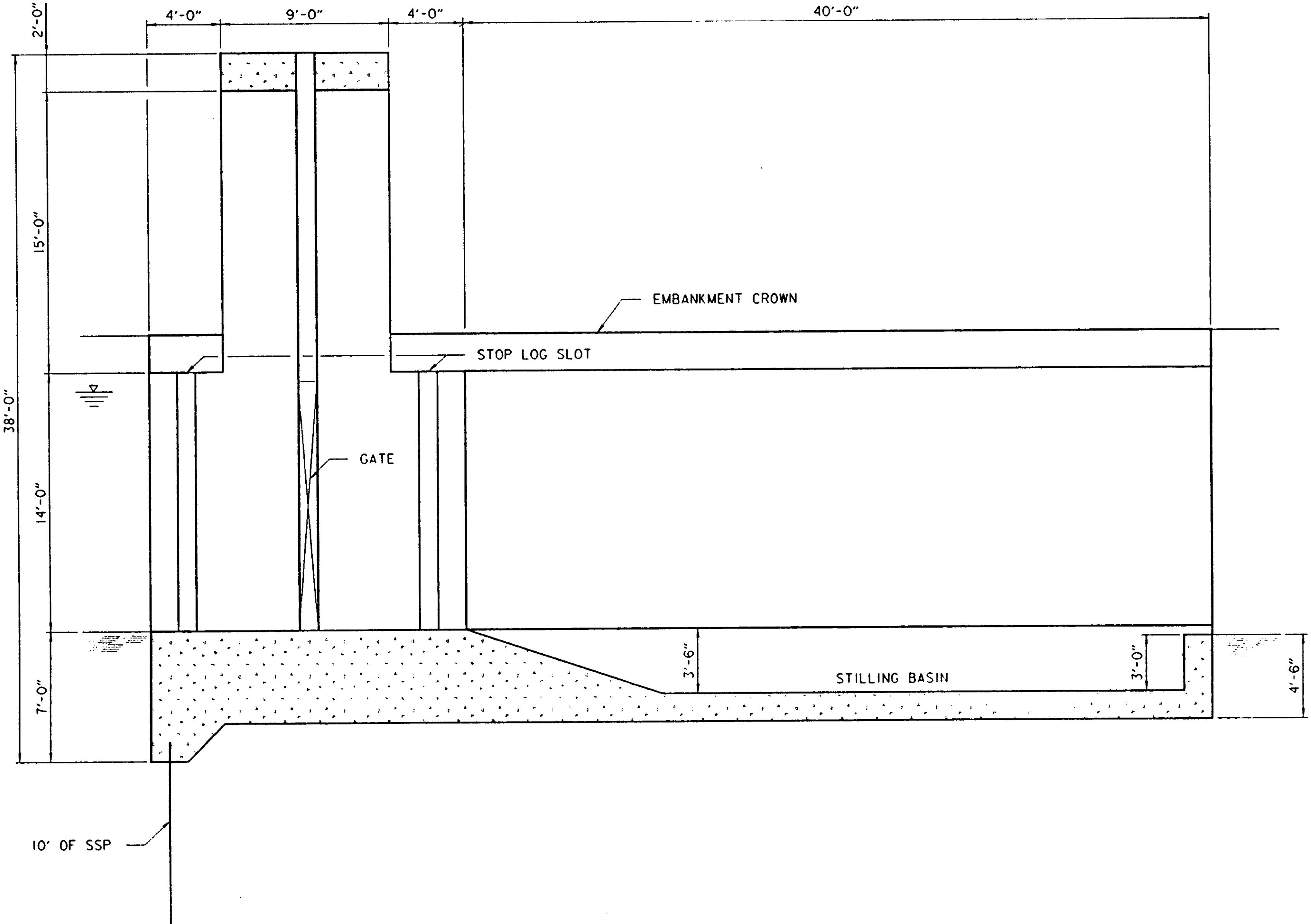
US Army Corps of Engineers

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

**CHECK STRUCTURE**

PLATE
IV-B-I




## LONGITUDINAL SECTION

SCALE 1/8" = 1'-0"

US Army Corps of Engineers

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

# CHECK STRUCTURE

PLATE
IV-B-II

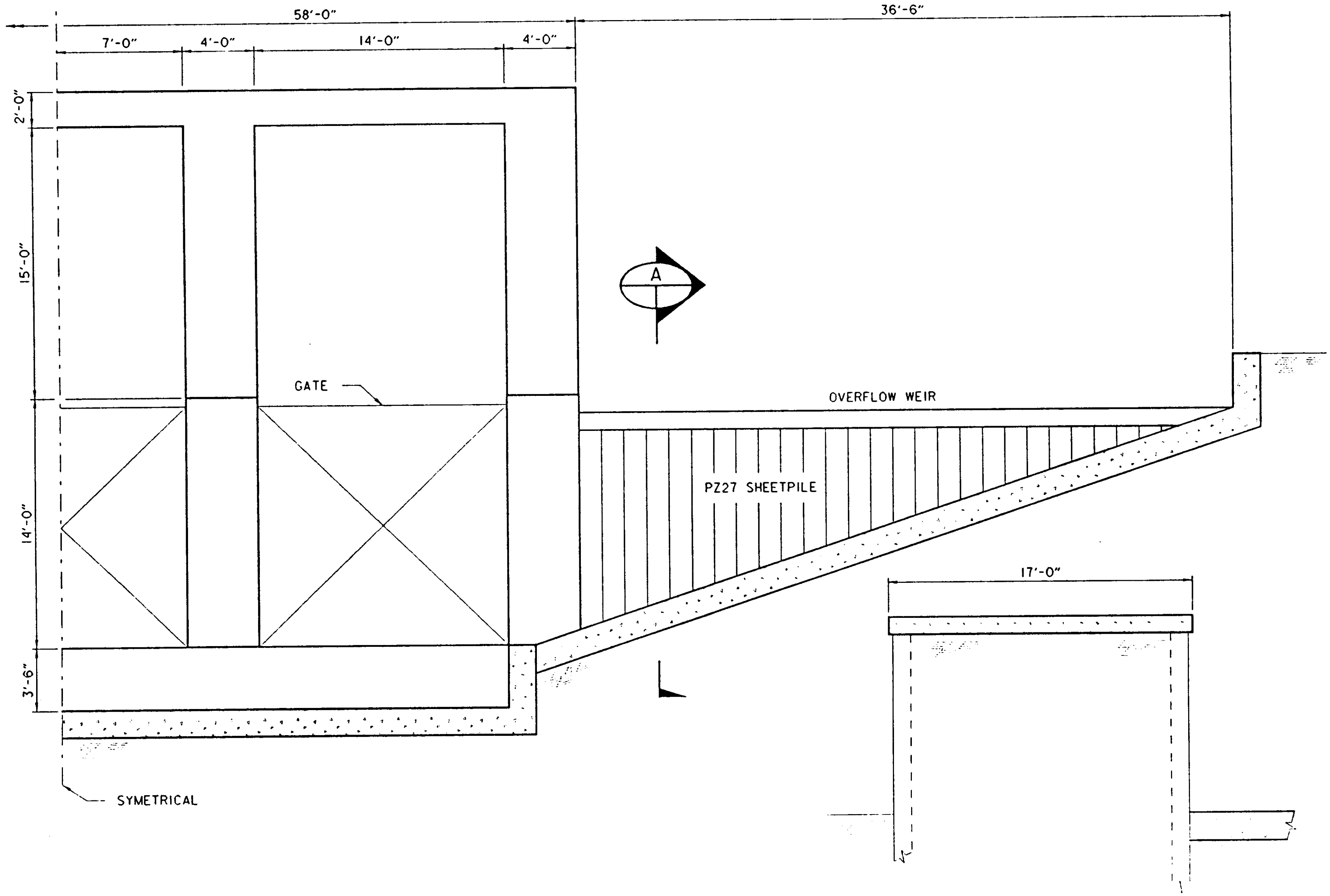
US Army Corps of Engineers

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

# CHECK STRUCTURE

PLATE
IV-B-III




**TRANSVERSE SECTION**
SCALE 1/8" = 1'-0"

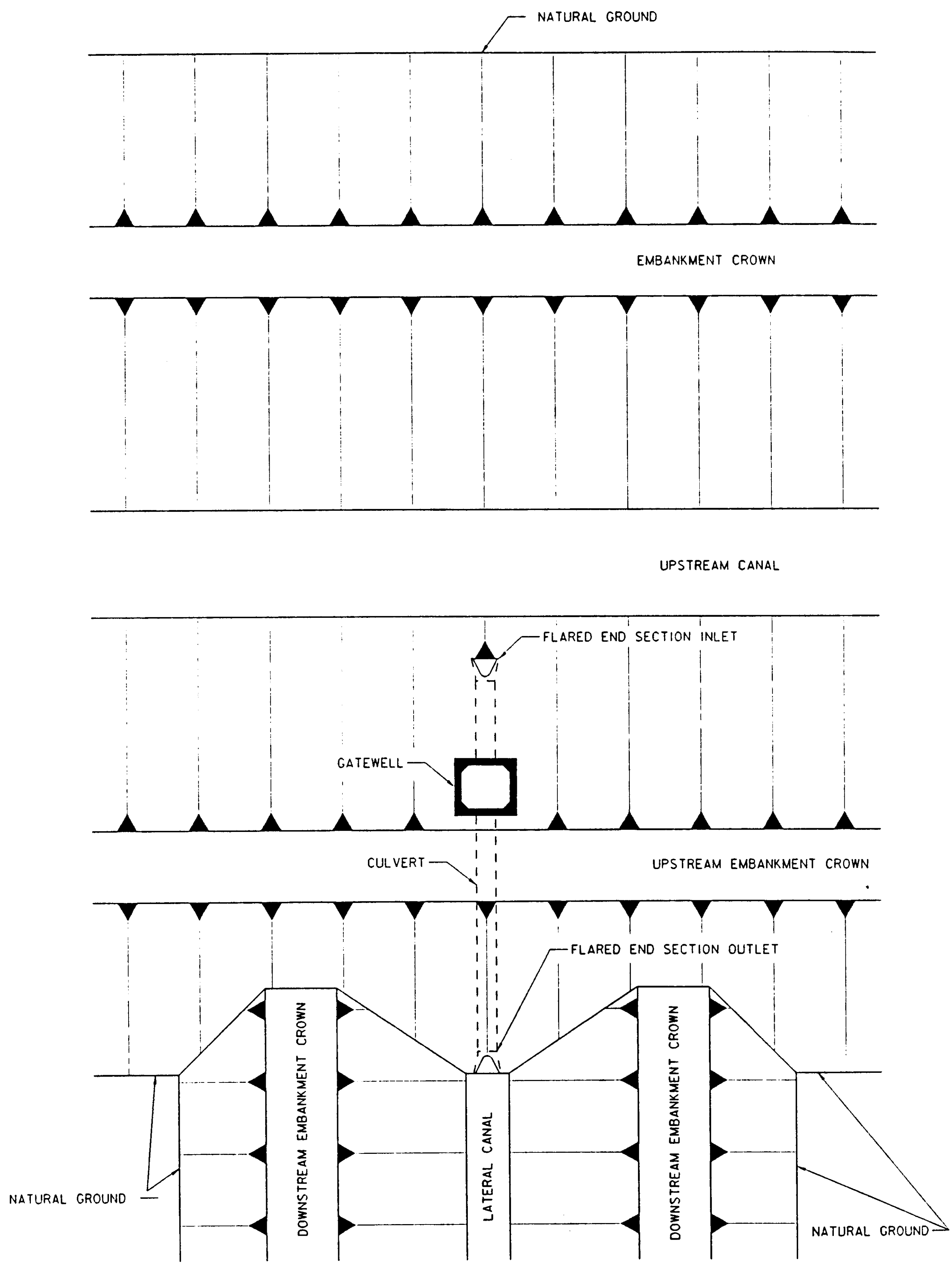
**SECTION** A
SCALE 1/8" = 1'-0"

# Grand Prairie Area Demonstration Project
**Structural, Electrical & Mechanical**

# APPENDIX IV-C

# GATEWELL STRUCTURES

**U.S. Army Corps of Engineers**
**Memphis District**




**TYPICAL SITE LAYOUT**

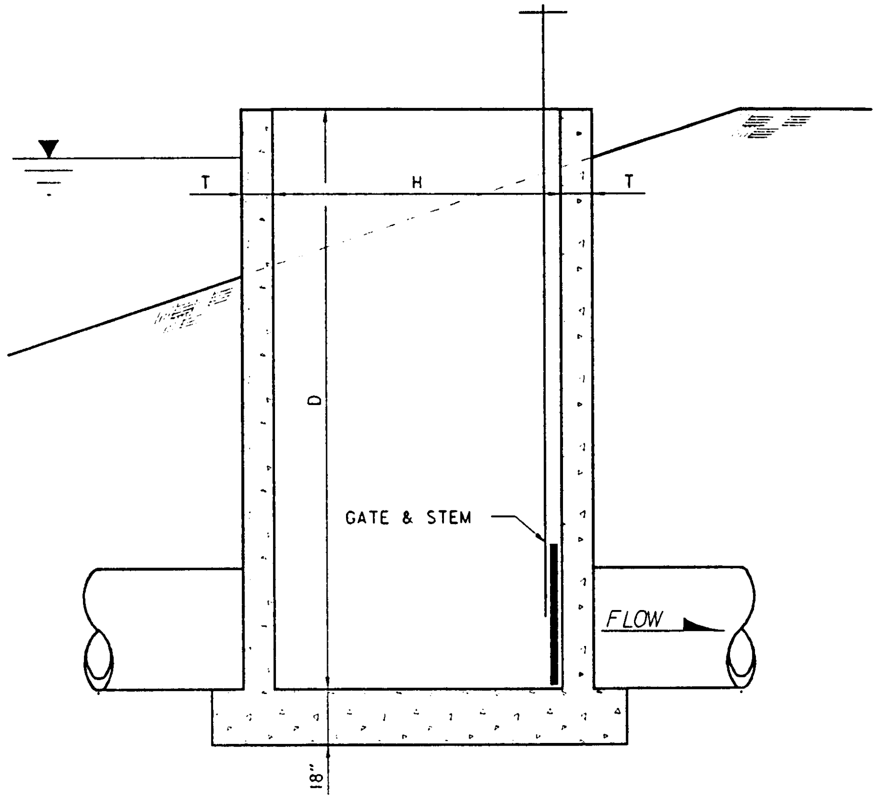
N.T.S.

US Army Corps of Engineers

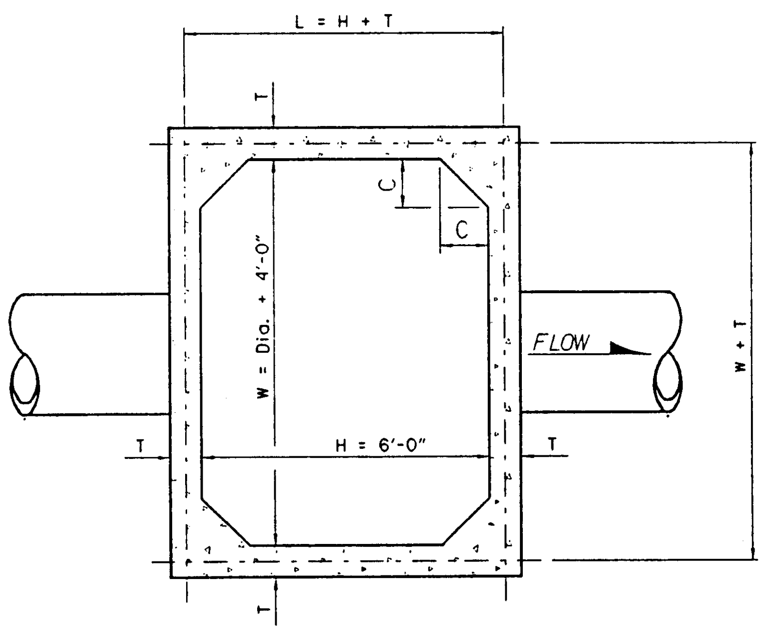
U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT
TURNOUTS, WASTEWAYS AND
CONDUIT CHECK STRUCTURES

PLATE
IV-C-I




VERTICAL




HORIZONTAL

## SECTIONS

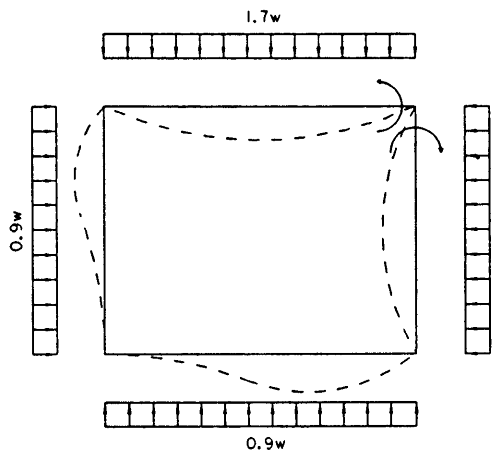
N.T.S.

US Army Corps of Engineers

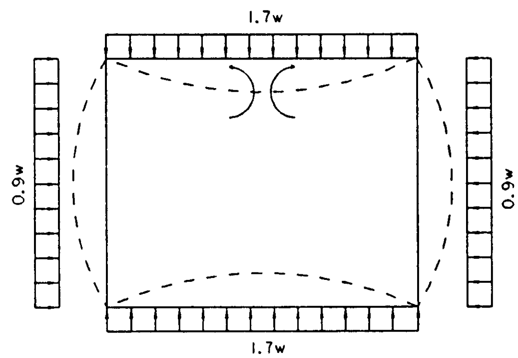
U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT
TURNOUTS, WASTEWAYS AND
CONDUIT CHECK STRUCTURES

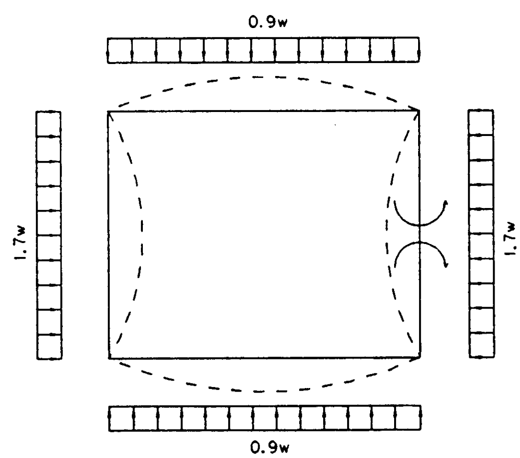
PLATE
IV-C-II




**Maximum Negative Moment**
N.T.S.




**Maximum Positive Moment – Top/Bot.**
N.T.S.




**Maximum Positive Moment – RT/LT**
N.T.S.

## HORIZONTAL LOADING DIAGRAMS
N.T.S.

US Army Corps of Engineers

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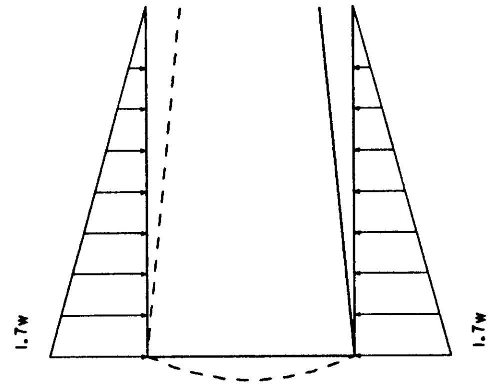
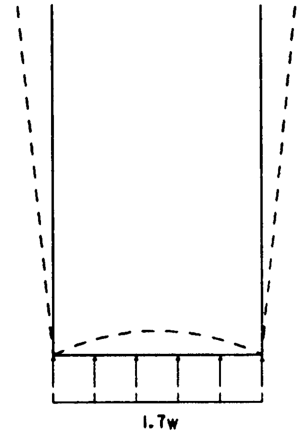
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT
TURNOUTS, WASTEWAYS AND CONDUIT CHECK STRUCTURES

PLATE
IV-C-III

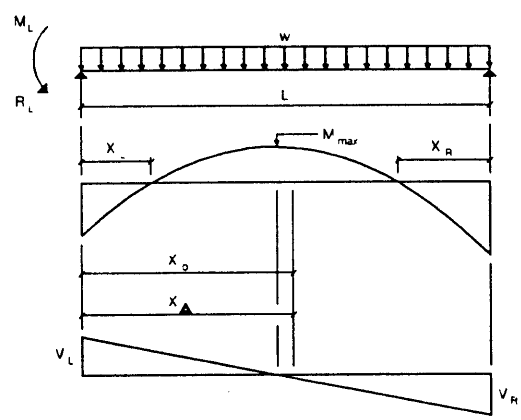



**Maximum Negative Moment**
N.T.S.




**Maximum Positive Moment**
N.T.S.

## BASE SLAB - VERTICAL LOADING DIAGRAMS
N.T.S.




**Typical Shear and Moment Diagrams**
N.T.S.

US Army Corps of Engineers

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT
TURNOUTS, WASTEWAYS AND
CONDUIT CHECK STRUCTURES

PLATE
IV-C-IV

## Gatewell Analysis & Design

**Description**

The following presents a typical analysis and design data using a single shaft gatewell that is 6 ft. wide, 6 ft. high and 8 ft. deep.

The width (W) of the gatewell is transverse to the pipe flow. The height (H) is parallel pipe flow (see Plate IV-C-II). Required widths were calculated by adding four feet to all pipes ranging from 18" to 96" and rounding up to the nearest foot. The four foot allows for a one foot clearance and a one foot fillet on each side of the pipe. The height (H) was arbitrarily fixed at six feet.

Lateral earth pressures were calculated using an equivalent fuild pressure of 94 pounds per cubic foot. Gatewells will be placed on the upstream side of a turnout embankment. It was assumed that the canals would remain full for extended periods of time. Backfill and water was assumed to extend up to one foot below the top of the gatewell. Analyses and designs have been completed for depths of eight feet to twenty four feet in four foot increments.

Vertical moments were calculated using tables published by the Bueau of Reclamation, (see page IV-C-5). The table used assumed a thin plate free at the top, hinged on the sides and fixed on the bottom. This will bracket the high end of the vertical moments.

Horizontal moments were determined assuming an infinitely deep gatewell and caluclating moments in a one foot horizontal strip at a depth equal to the depth of the gatewell in consideration. Three moment distributions were completed. The moment distributions were used to evaluate three load cases (see Plate IV-C-III and pages IV-C-3 thru 5). The load cases determined the maximum negative moments at the corners and positive moments in the transverse and parallel walls. Maximum negative moments at corners were evaluated by loading a top and side with 1.7 times the live load and the opposite side and top with 0.9 times the live load. Maximum positive moments in the two transverse walls were evaluated by loading the transverse walls with 1.7 times the live load, while the parallel walls were loaded with 0.9 times the live load. Load factors were reversed for maximum positive moments in the parallel walls.

**Defined Units**

$kips \equiv 1000 \cdot lbf$ $\quad$ $kip \equiv 1000 \cdot lbf$ $\quad$ $ksi \equiv 1000 \cdot psi$ $\quad$ $kcf := \frac{kip}{ft^2}$

PROJECT: Grand Prairie Demonstration Project
Eastern Arkansas

Computation Sheet

SUBJECT: Gate Well Structures

# SINGLE BOX GATEWELL

| | | | | | Stiffness | | | Uniform Loads | |
|---|---|---|---|---|---|---|---|---|---|
| Width | **6.00'** | Span W | **6.50'** | | 0.154 | Unit Load | | Top | 1.7 K/Ft |
| Height | **6.00'** | Span H | **6.50'** | | 0.154 | Wu = 1 Kip | | Bottom | 0.9 K/Ft |
| Thickness | **6.00"** | | | Sum | 0.308 | | | Right | 1.7 K/Ft |
| | | | | | | | | Left | 0.9 K/Ft |

| | Bottom | Left | Left | Top | Top | Right | Right | Bottom |
|---|---|---|---|---|---|---|---|---|
| Coef. | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 |
| | 3.169 | -3.169 | 3.169 | -5.985 | 5.985 | -5.985 | 5.985 | -3.169 |
| | 0.000 | 0.000 | 1.408 | 1.408 | 0.000 | 0.000 | -1.408 | -1.408 |
| | -0.704 | 0.704 | 0.000 | 0.000 | 0.704 | -0.704 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Moments | 2.465 | -2.465 | 4.577 | -4.577 | 6.690 | -6.690 | 4.577 | -4.577 |

**Maximum Negative Moment in Corners = 6.690**

DESIGN BY: Mike Watson
CHECKED BY: WET

APPENDIX IV-C-2

6/19/97

Report.MCD

APPENDIX IV-C-3

6/19/97

PROJECT: Grand Prairie Demonstration Project
Eastern Arkansas

SUBJECT: Gate Well Structures

Computation Sheet

DESIGN BY: Mike Watson

CHECKED BY: WET

# SINGLE BOX GATEWELL

| | | | | Stiffness | | Uniform Loads | |
|---|---|---|---|---|---|---|---|
| Width | 6.00' | Span W | 6.50' | 0.154 | Unit Load | Top | 1.7 K/Ft |
| Height | 6.00' | Span H | 6.50' | 0.154 | Wu = 1 Kip | Bottom | 1.7 K/Ft |
| Thickness | 6.00" | | Sum | 0.308 | | Right | 0.9 K/Ft |
| | | | | | | Left | 0.9 K/Ft |

| | Bottom | Left | | Top | | Right | | Bottom |
|---|---|---|---|---|---|---|---|---|
| Coef. | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 |
| | 5.985 | -3.169 | 3.169 | -5.985 | 5.985 | -3.169 | 3.169 | -5.985 |
| | -1.408 | -1.408 | 1.408 | 1.408 | -1.408 | -1.408 | 1.408 | 1.408 |
| | 0.704 | 0.704 | -0.704 | -0.704 | 0.704 | 0.704 | -0.704 | -0.704 |
| | -0.704 | -0.704 | 0.704 | 0.704 | -0.704 | -0.704 | 0.704 | 0.704 |
| | 0.352 | 0.352 | -0.352 | -0.352 | 0.352 | 0.352 | -0.352 | -0.352 |
| | -0.352 | -0.352 | 0.352 | 0.352 | -0.352 | -0.352 | 0.352 | 0.352 |
| | 0.176 | 0.176 | -0.176 | -0.176 | 0.176 | 0.176 | -0.176 | -0.176 |
| | -0.176 | -0.176 | 0.176 | 0.176 | -0.176 | -0.176 | 0.176 | 0.176 |
| | 0.088 | 0.088 | -0.088 | -0.088 | 0.088 | 0.088 | -0.088 | -0.088 |
| | -0.088 | -0.088 | 0.088 | 0.088 | -0.088 | -0.088 | 0.088 | 0.088 |
| | 0.044 | 0.044 | -0.044 | -0.044 | 0.044 | 0.044 | -0.044 | -0.044 |
| | -0.044 | -0.044 | 0.044 | 0.044 | -0.044 | -0.044 | 0.044 | 0.044 |
| | 0.022 | 0.022 | -0.022 | -0.022 | 0.022 | 0.022 | -0.022 | -0.022 |
| | -0.022 | -0.022 | 0.022 | 0.022 | -0.022 | -0.022 | 0.022 | 0.022 |
| | 0.011 | 0.011 | -0.011 | -0.011 | 0.011 | 0.011 | -0.011 | -0.011 |
| | -0.011 | -0.011 | 0.011 | 0.011 | -0.011 | -0.011 | 0.011 | 0.011 |
| | 0.006 | 0.006 | -0.006 | -0.006 | 0.006 | 0.006 | -0.006 | -0.006 |
| | -0.006 | -0.006 | 0.006 | 0.006 | -0.006 | -0.006 | 0.006 | 0.006 |
| | 0.003 | 0.003 | -0.003 | -0.003 | 0.003 | 0.003 | -0.003 | -0.003 |
| | -0.003 | -0.003 | 0.003 | 0.003 | -0.003 | -0.003 | 0.003 | 0.003 |
| | 0.001 | 0.001 | -0.001 | -0.001 | 0.001 | 0.001 | -0.001 | -0.001 |
| | -0.001 | -0.001 | 0.001 | 0.001 | -0.001 | -0.001 | 0.001 | 0.001 |
| | 0.001 | 0.001 | -0.001 | -0.001 | 0.001 | 0.001 | -0.001 | -0.001 |
| Moments | 4.578 | -4.576 | 4.576 | -4.578 | 4.578 | -4.576 | 4.576 | -4.578 |

**Maximum Positive Moment in Top & Bottom Wall = Mneg + wL^2/8 =** $\boxed{4.400}$

Report.MCD

APPENDIX IV-C-4

6/19/97

PROJECT: Grand Prairie Demostration Project
Eastern Arkansas

SUBJECT: Gate Well Structures

Computation Sheet

DESIGN BY: Mike Watson

CHECKED BY: WET

# SINGLE BOX GATEWELL

| | | | | | Stiffness | | | Uniform Loads | |
|---|---|---|---|---|---|---|---|---|---|
| Width | 6.00' | Span W | 6.50' | | 0.154 | Unit Load | | Top | 0.9 K/Ft |
| Height | 6.00' | Span H | 6.50' | | 0.154 | Wu = 1 Kip | | Bottom | 0.9 K/Ft |
| Thickness | 6.00" | | | Sum | 0.308 | | | Right | 1.7 K/Ft |
| | | | | | | | | Left | 1.7 K/Ft |

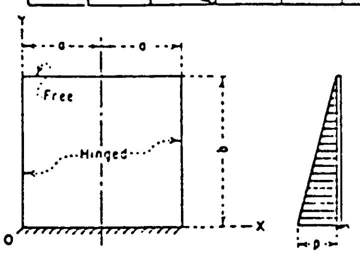
| | Bottom | Left | Left | Top | Top | Right | Right | Bottom |
|---|---|---|---|---|---|---|---|---|
| Coef. | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 |
| | 3.169 | -5.985 | 5.985 | -3.169 | 3.169 | -5.985 | 5.985 | -3.169 |
| | 1.408 | 1.408 | -1.408 | -1.408 | 1.408 | 1.408 | -1.408 | -1.408 |
| | -0.704 | -0.704 | 0.704 | 0.704 | -0.704 | -0.704 | 0.704 | 0.704 |
| | 0.704 | 0.704 | -0.704 | -0.704 | 0.704 | 0.704 | -0.704 | -0.704 |
| | -0.352 | -0.352 | 0.352 | 0.352 | -0.352 | -0.352 | 0.352 | 0.352 |
| | 0.352 | 0.352 | -0.352 | -0.352 | 0.352 | 0.352 | -0.352 | -0.352 |
| | -0.176 | -0.176 | 0.176 | 0.176 | -0.176 | -0.176 | 0.176 | 0.176 |
| | 0.176 | 0.176 | -0.176 | -0.176 | 0.176 | 0.176 | -0.176 | -0.176 |
| | -0.088 | -0.088 | 0.088 | 0.088 | -0.088 | -0.088 | 0.088 | 0.088 |
| | 0.088 | 0.088 | -0.088 | -0.088 | 0.088 | 0.088 | -0.088 | -0.088 |
| | -0.044 | -0.044 | 0.044 | 0.044 | -0.044 | -0.044 | 0.044 | 0.044 |
| | 0.044 | 0.044 | -0.044 | -0.044 | 0.044 | 0.044 | -0.044 | -0.044 |
| | -0.022 | -0.022 | 0.022 | 0.022 | -0.022 | -0.022 | 0.022 | 0.022 |
| | 0.022 | 0.022 | -0.022 | -0.022 | 0.022 | 0.022 | -0.022 | -0.022 |
| | -0.011 | -0.011 | 0.011 | 0.011 | -0.011 | -0.011 | 0.011 | 0.011 |
| | 0.011 | 0.011 | -0.011 | -0.011 | 0.011 | 0.011 | -0.011 | -0.011 |
| | -0.006 | -0.006 | 0.006 | 0.006 | -0.006 | -0.006 | 0.006 | 0.006 |
| | 0.006 | 0.006 | -0.006 | -0.006 | 0.006 | 0.006 | -0.006 | -0.006 |
| | -0.003 | -0.003 | 0.003 | 0.003 | -0.003 | -0.003 | 0.003 | 0.003 |
| | 0.003 | 0.003 | -0.003 | -0.003 | 0.003 | 0.003 | -0.003 | -0.003 |
| | -0.001 | -0.001 | 0.001 | 0.001 | -0.001 | -0.001 | 0.001 | 0.001 |
| | 0.001 | 0.001 | -0.001 | -0.001 | 0.001 | 0.001 | -0.001 | -0.001 |
| | -0.001 | -0.001 | 0.001 | 0.001 | -0.001 | -0.001 | 0.001 | 0.001 |
| Moments | 4.576 | -4.578 | 4.578 | -4.576 | 4.576 | -4.578 | 4.578 | -4.576 |

**Maximum Positive Moment in Right & Left Wall = Mneg + wL^2/8 =** $\boxed{4.402}$

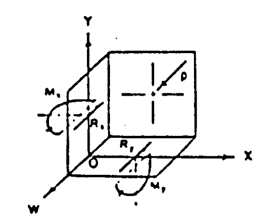
**Maximum Design Moment =** $\boxed{6.690}$

RESULTS

| | | | $M_x$ | | | | | | $M_y$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $y/b$ | $R_x$ \ $x/c$ | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 |
| $a/b = 1/8$ | 1.0 | +.0094 | 0 | -.0003 | -.0006 | -.0008 | -.0010 | -.0010 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.8 | +.0253 | 0 | -.0006 | -.0011 | -.0015 | -.0017 | -.0017 | 0 | -.0001 | -.0002 | -.0002 | -.0002 | -.0003 |
| | 0.6 | +.0500 | 0 | -.0011 | -.0020 | -.0026 | -.0030 | -.0031 | 0 | -.0002 | -.0004 | -.0005 | -.0006 | -.0006 |
| | 0.4 | +.0758 | 0 | -.0016 | -.0028 | -.0037 | -.0042 | -.0044 | 0 | -.0004 | -.0007 | -.0009 | -.0011 | -.0011 |
| | 0.2 | +.0833 | 0 | -.0015 | -.0028 | -.0036 | -.0041 | -.0042 | 0 | -.0006 | -.0010 | -.0013 | -.0015 | -.0016 |
| | 0 | +.0043 | 0 | +.0004 | +.0008 | +.0010 | +.0012 | +.0012 | 0 | +.0021 | +.0039 | +.0051 | +.0058 | +.0061 |
| | | $R_x$ \ $R_y$ | +.0043 | -.0775 | +.1180 | +.1417 | +.1551 | +.1591 | | | | | | |
| $a/b = 1/4$ | 1.0 | +.0249 | 0 | -.0022 | -.0040 | -.0054 | -.0062 | -.0065 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.8 | +.0548 | 0 | -.0029 | -.0051 | -.0067 | -.0077 | -.0081 | 0 | -.0004 | -.0006 | -.0008 | -.0010 | -.0010 |
| | 0.6 | +.1014 | 0 | -.0040 | -.0070 | -.0091 | -.0104 | -.0108 | 0 | -.0012 | -.0021 | -.0029 | -.0032 | -.0033 |
| | 0.4 | +.1388 | 0 | -.0046 | -.0078 | -.0100 | -.0113 | -.0117 | 0 | -.0019 | -.0034 | -.0046 | -.0052 | -.0055 |
| | 0.2 | +.1003 | 0 | -.0033 | -.0053 | -.0065 | -.0071 | -.0072 | 0 | -.0018 | -.0031 | -.0041 | -.0046 | -.0048 |
| | 0 | -.0513 | 0 | +.0014 | +.0025 | +.0033 | +.0038 | +.0040 | 0 | +.0071 | +.0127 | +.0167 | +.0191 | +.0199 |
| | | $R_x$ \ $R_y$ | -.0513 | +.1404 | +.2080 | +.2476 | +.2693 | +.2754 | | | | | | |
| $a/b = 3/8$ | 1.0 | +.0631 | 0 | -.0054 | -.0099 | -.0133 | -.0154 | -.0160 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.8 | +.0852 | 0 | -.0060 | -.0108 | -.0142 | -.0163 | -.0170 | 0 | -.0011 | -.0020 | -.0026 | -.0030 | -.0031 |
| | 0.6 | +.1388 | 0 | -.0071 | -.0122 | -.0155 | -.0176 | -.0183 | 0 | -.0027 | -.0050 | -.0066 | -.0076 | -.0079 |
| | 0.4 | +.1701 | 0 | -.0070 | -.0116 | -.0143 | -.0158 | -.0162 | 0 | -.0038 | -.0069 | -.0091 | -.0104 | -.0103 |
| | 0.2 | +.0890 | 0 | -.0044 | -.0064 | -.0071 | -.0074 | -.0074 | 0 | -.0021 | -.0033 | -.0040 | -.0043 | -.0044 |
| | 0 | -.0960 | 0 | +.0025 | +.0045 | +.0059 | +.0068 | +.0071 | 0 | +.0124 | +.0225 | +.0296 | +.0339 | +.0353 |
| | | $R_x$ \ $R_y$ | -.0960 | +.1886 | +.2717 | +.3203 | +.3458 | +.3538 | | | | | | |
| $a/b = 1/2$ | 1.0 | +.1322 | 0 | -.0087 | -.0159 | -.0210 | -.0241 | -.0252 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.8 | +.1049 | 0 | -.0090 | -.0159 | -.0207 | -.0235 | -.0244 | 0 | -.0021 | -.0038 | -.0050 | -.0058 | -.0061 |
| | 0.6 | +.1584 | 0 | -.0096 | -.0161 | -.0201 | -.0224 | -.0231 | 0 | -.0045 | -.0090 | -.0106 | -.0121 | -.0127 |
| | 0.4 | +.1757 | 0 | -.0087 | -.0136 | -.0161 | -.0173 | -.0176 | 0 | -.0053 | -.0092 | -.0119 | -.0134 | -.0139 |
| | 0.2 | +.0595 | 0 | -.0047 | -.0060 | -.0060 | -.0058 | -.0057 | 0 | -.0011 | -.0010 | -.0004 | +.0002 | +.0005 |
| | 0 | -.1169 | 0 | +.0040 | +.0070 | +.0091 | +.0103 | +.0107 | 0 | +.0199 | +.0351 | +.0455 | +.0515 | +.0535 |
| | | $R_x$ \ $R_y$ | -.1169 | +.2296 | +.3261 | +.3786 | +.4050 | +.4130 | | | | | | |
| $a/b = 3/4$ | 1.0 | +.3017 | 0 | -.0132 | -.0230 | -.0292 | -.0326 | -.0337 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.8 | +.1125 | 0 | -.0129 | -.0214 | -.0265 | -.0291 | -.0299 | 0 | -.0035 | -.0065 | -.0085 | -.0098 | -.0102 |
| | 0.6 | +.1595 | 0 | -.0126 | -.0194 | -.0227 | -.0242 | -.0246 | 0 | -.0065 | -.0114 | -.0145 | -.0162 | -.0168 |
| | 0.4 | +.1576 | 0 | -.0104 | -.0142 | -.0151 | -.0152 | -.0152 | 0 | -.0060 | -.0093 | -.0109 | -.0114 | -.0115 |
| | 0.2 | +.0115 | 0 | -.0043 | -.0036 | -.0021 | -.0011 | -.0007 | 0 | +.0030 | +.0080 | +.0129 | +.0161 | +.0172 |
| | 0 | -.1259 | 0 | +.0070 | +.0119 | +.0151 | +.0168 | +.0174 | 0 | +.0348 | +.0594 | +.0753 | +.0842 | +.0871 |
| | | $R_x$ \ $R_y$ | -.1259 | +.2925 | +.3991 | +.4504 | +.4744 | +.4816 | | | | | | |
| $a/b = 1$ | 1.0 | +.4312 | 0 | -.0154 | -.0247 | -.0293 | -.0312 | -.0317 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.8 | +.1046 | 0 | -.0147 | -.0224 | -.0255 | -.0263 | -.0270 | 0 | -.0043 | -.0073 | -.0093 | -.0103 | -.0106 |
| | 0.6 | +.1468 | 0 | -.0139 | -.0191 | -.0205 | -.0205 | -.0204 | 0 | -.0073 | -.0115 | -.0135 | -.0143 | -.0145 |
| | 0.4 | +.1380 | 0 | -.0109 | -.0125 | -.0117 | -.0107 | -.0103 | 0 | -.0050 | -.0059 | -.0048 | -.0035 | -.0029 |
| | 0.2 | -.0109 | 0 | -.0032 | -.0006 | +.0020 | +.0036 | +.0041 | 0 | +.0082 | +.0186 | +.0275 | +.0331 | +.0350 |
| | 0 | -.1123 | 0 | +.0095 | +.0159 | +.0198 | +.0219 | +.0226 | 0 | +.0482 | +.0797 | +.0990 | +.1094 | +.1128 |
| | | $R_x$ \ $R_y$ | -.1123 | +.3359 | +.4399 | +.4841 | +.5035 | +.5050 | | | | | | |
| $a/b = 3/2$ | 1.0 | +.5418 | 0 | -.0175 | -.0229 | -.0223 | -.0205 | -.0197 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0.8 | +.0931 | 0 | -.0164 | -.0201 | -.0188 | -.0158 | -.0160 | 0 | -.0048 | -.0069 | -.0073 | -.0070 | -.0069 |
| | 0.6 | +.1335 | 0 | -.0149 | -.0160 | -.0135 | -.0113 | -.0105 | 0 | -.0073 | -.0086 | -.0073 | -.0055 | -.0050 |
| | 0.4 | +.1257 | 0 | -.0104 | -.0033 | -.0050 | -.0027 | -.0019 | 0 | -.0023 | +.0025 | +.0086 | +.0129 | +.0144 |
| | 0.2 | -.0072 | 0 | -.0008 | +.0043 | +.0080 | +.0101 | +.0108 | 0 | +.0178 | +.0365 | +.0501 | +.0579 | +.0604 |
| | 0 | -.0724 | 0 | +.0139 | +.0216 | +.0258 | +.0279 | +.0295 | 0 | +.0694 | +.1079 | +.1289 | +.1394 | +.1426 |
| | | $R_y$ | -.0724 | +.3914 | +.4785 | +.5050 | +.5149 | +.5163 | | | | | | |




Moment = (Coefficient) $(pb^2)$
Reaction = (Coefficient) $(pb)$




POSITIVE SIGN CONVENTION

FIGURE 21.—*Plate fixed along one edge—Hinged along two opposite edges, moment and reaction coefficients, Load IV, uniformly varying load.*

**Input Variables**

**Gatewell Dimensions:**

| | |
|---|---|
| Inside width: | $W := 6.0 \cdot ft$ |
| Inside height: | $H := 6.0 \cdot ft$ |
| Haunch dimension: | $C := 12 \cdot in$ |
| Wall thickness: | $T := 6 \cdot in$ |
| Depth: | $D := 8 \cdot ft$ |

**Concrete properties:**

| | |
|---|---|
| Design compressive strength of concrete: | $f_c := 4 \cdot ksi$ |
| Unit weight of concrete: | $w_c := 0.145 \cdot kcf$ |
| Weight of reinforced concrete: | $w_{rc} := 0.150 \cdot kcf$ |

**Steel properties:**

| | |
|---|---|
| Specified yield strength of reinforcement: | $f_y := 60 \cdot ksi$ |
| Steel modulus of elasticity: | $E_s := 29000 \cdot ksi$ |

**Unit weights:**

| | |
|---|---|
| Soil weight: | $\gamma_s := 0.125 \cdot kcf$ |
| Water weight: | $\gamma_w := 0.0624 \cdot kcf$ |

**Unit load used in analysis:**

| | |
|---|---|
| Unit uniformly distributed load per unit length: | $w_u := 1.00 \cdot \frac{kip}{ft}$ |

**End moments for maximum negative moment design:**
**(Two adjacent walls loaded)**

| | |
|---|---|
| Right end moment per unit load: | $M_{R1} := 6.69 \cdot kip \cdot ft$ |
| Left end moment per unit load: | $M_{L1} := 4.58 \cdot kip \cdot ft$ |

**End moments for maximum positive moment design:**
**(Two opposite walls loaded)**

| | |
|---|---|
| Right end moment per unit load: | $M_{R2} := 4.58 \cdot kip \cdot ft$ |
| Left end moment per unit load: | $M_{L2} := 4.58 \cdot kip \cdot ft$ |

**Load Factors:**

| | |
|---|---|
| Live load: | $LL := 1.7$ |
| Dead load: | $DL := 1.4$ |

**Design Variables**

$M_u$ = Factored ultimate moment capacity
$M_v$ = Factored vertical moment
$M_h$ = Factored horizontal moment

$V_u$ = Factored ultimate shear capacity
$V_v$ = Factored vertical shear
$V_h$ = Factored horizontal shear

$Bar_v$ = Vertical bar diameter
$Bar_h$ = Horizontal bar diameter

$b_v$ = Vertical bar spacing
$b_h$ = Horizontal bar spacing

$d$ = Distance from extreme compression fiber to centroid of vertical tension reinforcement
$d_n$ = Distance from inside face to centroid of horizontal negative tension reinforcement
$d_p$ = Distance from outside face to centroid of horizontal positive tension reinforcement

## Calculations

Span length: $L := \mathrm{if}(H>W, H, W) + T$ $L = 6.5 \cdot \mathrm{ft}$

Equivalent fluid pressure: $\gamma_e := \gamma_w + 0.5 \cdot (\gamma_s - \gamma_w)$ $\gamma_e = 0.094 \cdot \mathrm{kcf}$

**Vertical reinforcement:**

Reference: Moody, W.T., " Moments and Reactions for Rectangular Plates." *Engineering Monograph* No. 27, U.S. Bureau of Reclamation, Denver, 1960 (Revised 1963), Fig. 21, pg. 27

The larger value of H and W is used in the calculation of "a." This results in the largest vertical shear and moment.

$a := \dfrac{\mathrm{if}(H>W, H, W)}{2}$ $b_1 := D - 1 \cdot \mathrm{ft}$

$a = 3 \cdot \mathrm{ft}$ $b_1 = 7 \cdot \mathrm{ft}$ $LL = 1.7$ $w := LL \cdot \gamma_e$ $w = 0.159 \cdot \dfrac{\mathrm{kip}}{\mathrm{ft}^2}$

Interpolation from table:

$w_i := 0.375$ $y_i := 0.0353$

$\dfrac{a}{b_1} = 0.429$

$x_i := 0.500$ $z_i := 0.0535$

$$Coef := \left[\frac{\dfrac{a}{b_1} - w_i}{x_i - w_i} \cdot (z_i - y_i)\right] + y_i \qquad Coef = 0.0431$$

Vertical moment: $M_v := Coef \cdot w \cdot b_1^{\,3}$ $M_v = 2.355 \cdot \mathrm{kip} \cdot \mathrm{ft}$

Try: $Bar_v := \dfrac{4}{8} \cdot \mathrm{in}$ $A_s := \dfrac{3.1416 \cdot Bar_v^{\,2}}{4}$ $A_s = 0.2 \cdot \mathrm{in}^2$

$b_v := 12 \cdot \mathrm{in}$ $cover := 1.5 \cdot \mathrm{in}$

Verical bars are assumed to be in the center of walls less than 10" thick.

$d := \dfrac{T}{2}$ $d = 3 \cdot \mathrm{in}$ $\phi := 0.9$ ACI Sec. 9.3.2.1

$\rho := \dfrac{A_s}{b_v \cdot d}$ $\rho = 0.0055$

$$M_u := d^2 \cdot b_v \cdot f_y \cdot \phi \cdot \rho \cdot \left(1 - 0.59 \cdot \frac{f_y \cdot \rho}{f_c}\right) \cdot \frac{12 \cdot \mathrm{in}}{b_v}$$

$M_u = 2.523 \cdot \mathrm{kip} \cdot \mathrm{ft}$

$M_u > M_v$ OK

Vertical shear:

$a = 3 \cdot ft$ $b_1 = 7 \cdot ft$ $w = 0.159 \cdot \frac{kip}{ft^2}$

$w_i = 0.375$ $y_i := 0.3538$

$\frac{a}{b_1} = 0.429$

$x_i = 0.5$ $z_i := 0.4130$

$Coef := \left[\frac{\frac{a}{b_1} - w_i}{x_i - w_i} \cdot (z_i - y_i)\right] + y_i$ $Coef = 0.3792$

$V_v := Coef \cdot w \cdot b_1^2$ $V_v = 2.96 \cdot kip$

$b_v = 12 \cdot in$ $d = 3 \cdot in$ $\phi := 0.85$ $f_c = 4 \cdot ksi$

$V_c := 2 \cdot \sqrt{f_c \cdot psi} \cdot b_v \cdot d \cdot \frac{12 \cdot in}{b_v}$ $V_u := \phi \cdot V_c$ $V_u = 3.871 \cdot kip$ ACI Sec. 11.3.1.1 & 11.5.5.1

$V_u > V_v$ OK

**Horizontal negative reinforcement:**

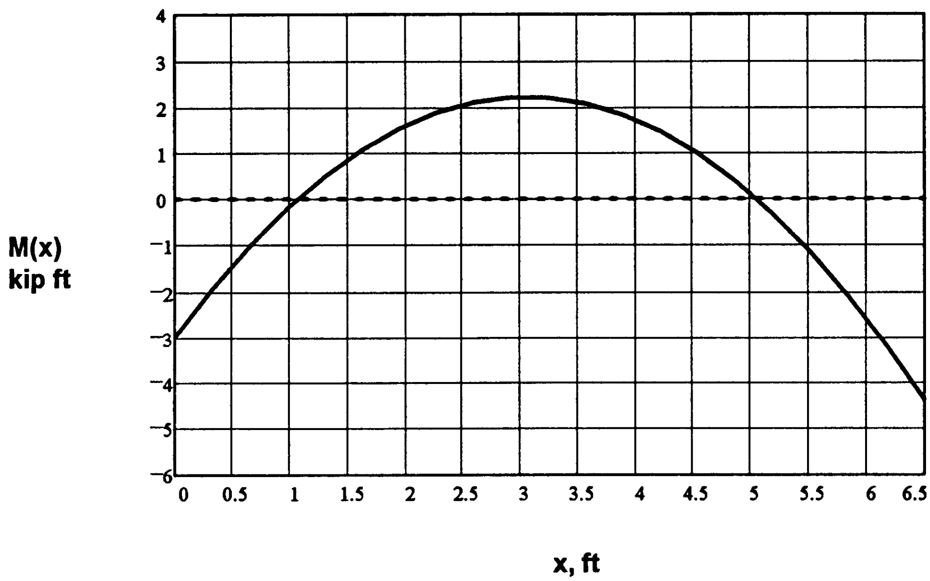
Horizontal bars are assumed to be positioned on the out side of the vertical bars, side closet to the earth. The distance "d" for negative moment is from the center of the horizontal bar to the inside face, face opposite the earth.

| | | |
|---|---|---|
| Uniform load @ depth D-1: | $w_D := \gamma_e \cdot (D - 1 \cdot ft)$ | $w_D = 0.656 \cdot \frac{kip}{ft}$ |
| Right end moment: | $M_R := \frac{w_D}{w_u} \cdot M_{R1}$ | $M_R = 4.388 \cdot kip \cdot ft$ |
| Left end moment: | $M_L := \frac{w_D}{w_u} \cdot M_{L1}$ | $M_L = 3.004 \cdot kip \cdot ft$ |
| Factored uniform load @ depth D-1: | $w := LL \cdot w_D$ | $w = 1.115 \cdot \frac{kip}{ft}$ |
| Left end reaction: | $R_L := \frac{w \cdot L}{2} + \left(\frac{M_L - M_R}{L}\right)$ | $R_L = 3.411 \cdot kips$ |
| Right end reaction: | $R_R := \frac{w \cdot L}{2} + \left(\frac{M_R - M_L}{L}\right)$ | $R_R = 3.837 \cdot kips$ |
| Location of the point of zero shear from the left end: | $X_o := \frac{R_L}{w}$ | $X_o = 3.059 \cdot ft$ |
| Shear as a function of distance x from the left end: | $V(x) := R_L - w \cdot x$ | |
| Moment as a function of distance x from the left end: | $M(x) := -M_L + R_L \cdot x - \frac{1}{2} \cdot w \cdot x^2$ | |

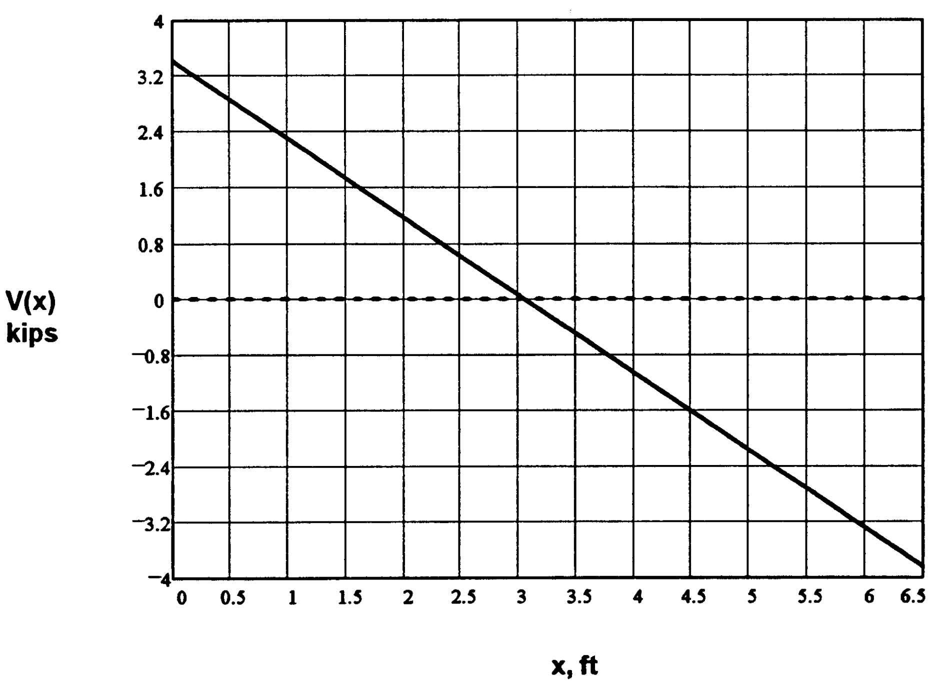
**Plot of moment M(x) versus x for N points across the span**

$N := 20$ $\qquad M_{max} := M(X_o)$ $\qquad M_{max} = 2.213 \cdot kip \cdot ft$

$x := 0 \cdot ft, \frac{L}{N} .. L$




**Plot of shear V(x) versus x for N points across the span**



$x_1 := \frac{T}{2}$ $\quad x_1 = 0.25 \cdot ft$ $\quad x_2 := L - \frac{T}{2}$ $\quad x_2 = 6.25 \cdot ft$

$M(x_1) = -2.186 \cdot kip \cdot ft$ $\quad M(x_2) = -3.464 \cdot kip \cdot ft$ ACI Sec. 8.7.3

$M_h := if(|M(x_1)| > |M(x_2)|, M(x_1), M(x_2))$ $\quad M_h = -3.464 \cdot kip \cdot ft$

$\beta_1 := if\left[f_c > 8 \cdot ksi, 0.65, if\left[f_c < 4 \cdot ksi, 0.85, 0.85 - \left(\frac{f_c - 4 \cdot ksi}{1 \cdot ksi}\right) \cdot 0.05\right]\right]$ $\quad \beta_1 = 0.85$ ACI 10.2.7.3

$\rho_b := 0.85 \cdot \beta_1 \cdot \frac{f_c}{f_y} \cdot \left(\frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$ $\quad \rho_{max} := 0.35 \cdot \rho_b$ $\quad \rho_{max} = 0.01$ ACI 10.3.3 & EM-1110-2-2104, pg 3-4

$\rho_{min} := 0.0018$ ACI 10.5.3 & 7.12

Try:

$Bar_h := \frac{5}{8} \cdot in$ $\quad A_s := \frac{3.1416 \cdot Bar_h^2}{4}$ $\quad A_s = 0.31 \cdot in^2$

$b_h := 12 \cdot in$ $\quad cover := 1.5 \cdot in$ $\quad \phi := 0.9$ ACI Sec. 9.3.2.1

$d_n := \frac{T}{2} + \frac{Bar_h + Bar_v}{2}$ $\quad d_n = 3.563 \cdot in$

$\rho := \frac{A_s}{b_h \cdot d_n}$ $\quad \rho = 0.0072$

$M_u := d_n^2 \cdot b_h \cdot f_y \cdot \phi \cdot \rho \cdot \left(1 - 0.59 \cdot \frac{f_y \cdot \rho}{f_c}\right) \cdot \frac{12 \cdot in}{b_h}$ $\quad M_u = 4.606 \cdot kip \cdot ft$

$M_u > M_h$ OK

Horizontal shear:

$V_h := V\left(\frac{T}{2} + C\right)$ $\quad V_h = 2.017 \cdot kip$

$b_h = 12 \cdot in$ $\quad d_n = 3.563 \cdot in$ $\quad \phi := 0.85$ ACI Sec. 9.3.2.3

$V_c := 2 \cdot \sqrt{f_c \cdot psi} \cdot b_h \cdot d_n \cdot \frac{12 \cdot in}{b_h}$ $\quad V_u := \phi \cdot V_c$ $\quad V_u = 4.596 \cdot kip$ ACI Sec. 11.3.1.1 & 11.5.5.1

$V_u > V_h$ OK

**Horizontal positive reinforcement:**

Horizontal bars are assumed to be positioned on the out side of the vertical bars, side closet to the earth. The distance "d" for positive moment is from the center of the horizontal bar to the outside face, face in contact with earth.

Uniform load @ depth D-1: $w_D := \gamma_e \cdot (D - 1 \cdot ft)$ $\qquad w_D = 0.656 \cdot \frac{kip}{ft}$

Right end moment: $M_R := \frac{w_D}{w_u} \cdot M_{R2}$ $\qquad M_R = 3.004 \cdot kip \cdot ft$

Left end moment: $M_L := \frac{w_D}{w_u} \cdot M_{L2}$ $\qquad M_L = 3.004 \cdot kip \cdot ft$

Factored uniform load @ depth D-1
: $w := LL \cdot w_D$ $\qquad w = 1.115 \cdot \frac{kip}{ft}$

Left end reaction: $R_L := \frac{w \cdot L}{2} + \left(\frac{M_L - M_R}{L}\right)$ $\qquad R_L = 3.624 \cdot kips$

Right end reaction: $R_R := \frac{w \cdot L}{2} + \left(\frac{M_R - M_L}{L}\right)$ $\qquad R_R = 3.624 \cdot kips$

Location of the point of zero shear from the left end: $X_o := \frac{R_L}{w}$ $\qquad X_o = 3.25 \cdot ft$

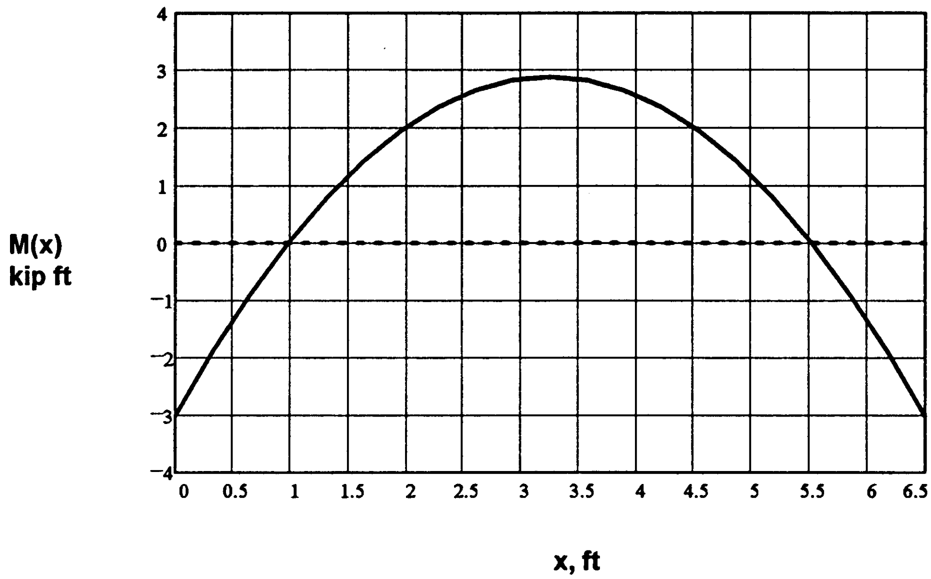
Shear as a function of distance x from the left end: $V(x) := R_L - w \cdot x$

Moment as a function of distance x from the left end: $M(x) := -M_L + R_L \cdot x - \frac{1}{2} \cdot w \cdot x^2$

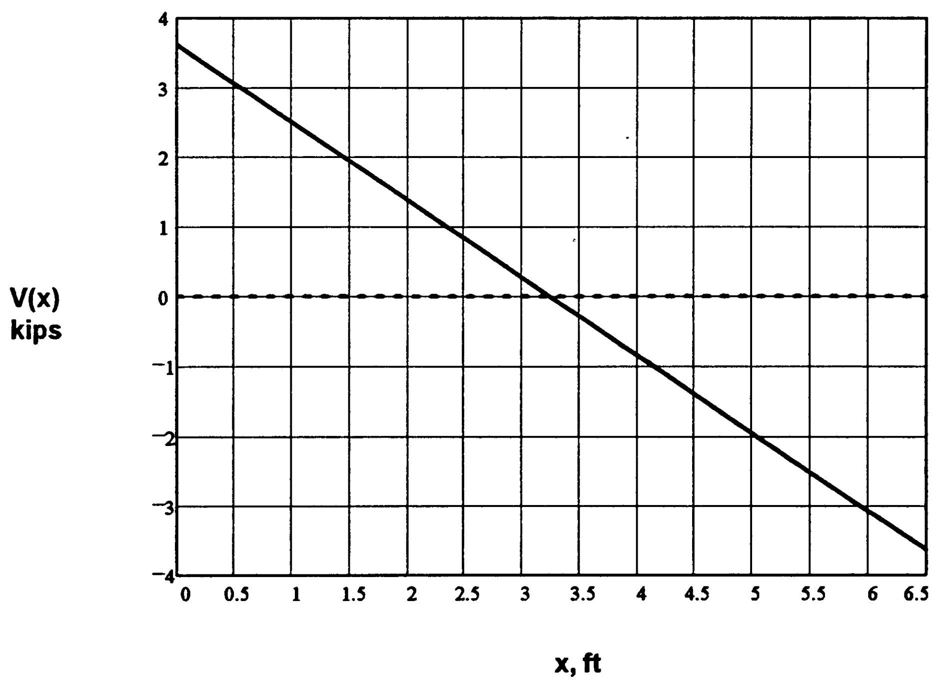
**Plot of moment M(x) versus x for N points across the span**

$N := 20$ $\quad M_{max} := M(X_o)$ $\quad M_{max} = 2.885 \cdot kip \cdot ft$

$$x := 0 \cdot ft, \frac{L}{N} .. L$$




**Plot of shear V(x) versus x for N points across the span**



Maximum positive or least negative moment: $M_{max} = 2.885 \cdot kip \cdot ft$

$\beta_1 := if\left[f_c > 8 \cdot ksi, 0.65, if\left[f_c < 4 \cdot ksi, 0.85, 0.85 - \left(\frac{f_c - 4 \cdot ksi}{1 \cdot ksi}\right) \cdot 0.05\right]\right]$ $\beta_1 = 0.85$ ACI 10.2.7.3

$\rho_b := 0.85 \cdot \beta_1 \cdot \frac{f_c}{f_y} \cdot \left(\frac{87 \cdot ksi}{87 \cdot ksi + f_y}\right)$ $\rho_{max} := 0.35 \cdot \rho_b$ $\rho_{max} = 0.01$ ACI 10.3.3 & EM-1110-2-2104, pg 3-4

$\rho_{min} := 0.0018$ ACI 10.5.3 & 7.12

Try:

$A_s = 0.31 \cdot in^2$ $b_h = 12 \cdot in$ $d_p := \frac{T}{2} - \frac{Bar_h + Bar_v}{2}$ $d_p = 2.437 \cdot in$

$\rho := \frac{A_s}{b_h \cdot d_p}$ $\rho = 0.0105$ $\phi := 0.9$ ACI Sec. 9.3.2.1

$M_u := d_p^{\,2} \cdot b_h \cdot f_y \cdot \phi \cdot \rho \cdot \left(1 - 0.59 \cdot \frac{f_y \cdot \rho}{f_c}\right) \cdot \frac{12 \cdot in}{b_h}$ $M_u = 3.053 \cdot kip \cdot ft$

$M_u > M_{max}$ OK

Horizontal shear:

$V_h := V\left(\frac{T}{2} + C\right)$ $V_h = 2.23 \cdot kip$

$b_h = 12 \cdot in$ $d_p = 2.437 \cdot in$ $\phi := 0.85$ ACI Sec. 9.3.2.3

$V_c := 2 \cdot \sqrt{f_c \cdot psi} \cdot b_h \cdot d_p \cdot \frac{12 \cdot in}{b_h}$ $V_u := \phi \cdot V_c$ $V_u = 3.145 \cdot kip$ ACI Sec. 11.3.1.1 & 11.5.5.1

$V_u > V_h$ OK

## Summary

| | | |
|---|---|---|
| Wall thickness: | $T = 6 \cdot in$ | |
| Vertical bars: | $size := Bar_v \cdot \frac{8}{in}$ | $size = 4$ |
| | $spacing := b_v$ | $spacing = 12 \cdot in$ |
| Horizontal Bars: | $size := Bar_h \cdot \frac{8}{in}$ | $size = 5$ |
| | $spacing := b_h$ | $spacing = 12 \cdot in$ |

# Table IV-C-1
## Gate Well Structures
## Conduit Check Structure Quantities

| GATED CONDUIT CHECK STRUCTURES | | | | | | QUANTITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Canal Number | Structure Name | Dimensions | | | | Pipe Length | End Sections | Concrete (cy) | Grating (sf) | Riprap (tn) | Handrail (Ft) |
| | | Pipe Runs | Diameter | Length (ft.) | Height (ft.) | | | | | | |
| 1500 | C-1500.01 | 2 | 18" | 52 | 7.0 | 68 | 4 | 19.3 | 72 | 45 | 55 |
| 6000 | C-6000.02 | 3 | 42" | 105 | 13.5 | 260 | 6 | 62.7 | 144 | 45 | 96 |
| 6000 | C-6000.03 | 2 | 30" | 94 | 12.0 | 152 | 4 | 30.1 | 84 | 45 | 59 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| 2200 | C-2200.01 | 2 | 48" | 67 | 9.5 | 98 | 4 | 32.3 | 96 | 45 | 64 |
| | | | | | | | | | | | |
| 3100 | C-3100.01 | 2 | 18" | 49 | 6.5 | 62 | 4 | 18.5 | 72 | 45 | 55 |
| | | | | | | | | | | | |
| 3200 | C-3200.01 | 2 | 24" | 67 | 9.5 | 98 | 4 | 23.5 | 72 | 45 | 55 |
| | | | | | | | | | | | |
| 3220 | C-3220.01 | 2 | 18" | 37 | 4.5 | 38 | 4 | 15.1 | 72 | 45 | 55 |
| | | | | | | | | | | | |
| 5200 | C-5200.01 | 2 | 24" | 101 | 13.0 | 166 | 4 | 29.4 | 72 | 45 | 55 |
| | | | | | | | | | | | |
| 5400 | C-5400.01 | 2 | 18" | 43 | 5.5 | 50 | 4 | 16.8 | 72 | 45 | 55 |
| | | | | | | | | | | | |
| 5500 | C-5500.01 | 2 | 48" | 55 | 7.5 | 74 | 4 | 27.6 | 96 | 45 | 64 |
| | | | | | | | | | | | |
| 6200 | C-6200.01 | 2 | 60" | 91 | 11.5 | 145 | 4 | 39.6 | 108 | 45 | 68 |
| 6200 | C-6200.02 | 2 | 24" | 94 | 12.0 | 152 | 4 | 27.7 | 72 | 45 | 55 |
| 6200 | C-6200.03 | 2 | 54" | 67 | 9.5 | 98 | 4 | 34.6 | 108 | 45 | 68 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| 6600 | C-6600.01 | 2 | 30" | 52 | 7.0 | 68 | 4 | 21.0 | 84 | 45 | 59 |

# Table IV-C-2
## Gate Well Structures
## Main Canal Turnout Quantities

| MAIN CANAL TURNOUTS | | | | | | QUANTITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Canal | Structure | | Turnout | | | Pipe | End | Concrete | Grating | Riprap | Handrail |
| Number | Name | Pipe Runs | Diameter | Length (Ft.) | Height (Ft.) | Length (Ft.) | Sections | (cy) | (sf) | (tn) | (Ft) |
| to 1000.01 | T-1000.01 | 1 | 18" | 94 | 12 | 76 | 2 | 13.9 | 36 | 45 | 27.3 |
| to 1100 | T-1100 | 1 | 18" | 94 | 12 | 76 | 2 | 13.9 | 36 | 45 | 27.3 |
| to 1200 | T-1200 | 1 | 18" | 94 | 12 | 76 | 2 | 13.9 | 36 | 45 | 27.3 |
| to 1300 | T-1300 | 1 | 18" | 87 | 11 | 69 | 2 | 13.0 | 36 | 45 | 27.3 |
| to 1400 | T-1400 | 1 | 18" | 87 | 11 | 69 | 2 | 13.0 | 36 | 45 | 27.3 |
| to 2300 | T-2300 | 1 | 18" | 64 | 9 | 46 | 2 | 11.3 | 36 | 45 | 27.3 |
| to 2100 | T-2100 | 1 | 24" | 83.5 | 10.5 | 66 | 2 | 12.6 | 36 | 45 | 27.3 |
| 1000 | | | | | | | | | | | |
| to 1500 | T-1500 | 1 | 48" | 104.5 | 13.5 | 87 | 2 | 20.9 | 48 | 45 | 32.0 |
| | | | | | | | | | | | |
| 2000 | | | | | | | | | | | |
| to 2000.01 | P-2000.01 | | Pump-5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 2200 | T-2200 | 1 | 42" | 90.5 | 11.5 | 73 | 2 | 18.5 | 48 | 45 | 32.0 |
| to 2000.02 | P-2000.02 | | Pump-5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 2400 | T-2400 | 1 | 36" | 83.5 | 10.5 | 66 | 2 | 13.7 | 42 | 45 | 29.3 |
| to 2000.03 | P-2000.03 | | Pump-10hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 2000.04 | P-2000.04 | | Pump-5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 2500 | T-2500 | 1 | 48" | 87 | 11 | 69 | 2 | 17.9 | 48 | 45 | 32.0 |
| | | | | | | | | | | | |
| 3000 | | | | | | | | | | | |
| to 3100 | T-3100 | 1 | 42" | 70 | 10 | 52 | 2 | 16.7 | 48 | 45 | 32.0 |
| to 3000.01 | P-3000.01 | | Pump-5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 3200 | EXT 3000 | | ------- | ------ | ------ | | | | | | |
| to 3300 | T-3300 | 1 | 30" | 87 | 11 | 69 | 2 | 14.1 | 42 | 45 | 29.3 |
| to 3400 | T-3400 | 1 | 30" | 83.5 | 10.5 | 66 | 2 | 13.7 | 42 | 45 | 29.3 |
| to 3000.02 | P-3000.02 | | Pump-20hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 3000.03 | P-3000.03 | | Pump-5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 3000.04 | P-3000.04 | | Pump-15hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 3000.05 | P-3000.05 | | Pump-10hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 3000.06 | P-3000.06 | | Pump-20hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 3000.07 | P-3000.07 | | Pump-10hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 3500A | T-3500A | 1 | 48" | 67 | 9.5 | 49 | 2 | 16.2 | 48 | 45 | 32.0 |
| to 3500B | T-3500B | 1 | 30" | 61 | 8.5 | 43 | 2 | 11.9 | 42 | 45 | 29.3 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| 4000 | | | | | | | | | | | |

# Table IV-C-2
# Gate Well Structures
# Main Canal Turnout Quantities

| MAIN CANAL TURNOUTS | | | | | | QUANTITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Canal Number | Structure Name | Pipe Runs | Turnout Diameter | Turnout Length (Ft.) | Turnout Height (Ft.) | Pipe Length (Ft.) | End Sections | Concrete (cy) | Grating (sf) | Riprap (tn) | Handrail (Ft) |
| to 4000.01 | P-4000.01 | 1 | Pump-5hp | 86 | 12 | 76 | 2 | 13.9 | 36 | 45 | 27.3 |
| to 4000.02 | P-4000.02 | | Pump-7.5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 4000.03 | P-4000.03 | | Pump-80hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 4100 | T-4100 | 1 | 30" | 61 | 8.5 | 43 | 2 | 11.9 | 42 | 45 | 29.3 |
| to 4000.04 | P-4000.04 | | Pump-5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 4200 | T-4200 | 1 | 30" | 61 | 8.5 | 43 | 2 | 11.9 | 42 | 45 | 29.3 |
| to 4000.05 | P-4000.05 | | Pump-40hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 4000.06 | P-4000.06 | | Pump-5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 4300 | T-4300 | 1 | 24" | 55 | 7.5 | 37 | 2 | 10.1 | 36 | 45 | 27.3 |
| to 4400 | T-4400 | 1 | 30" | 55 | 7.5 | 37 | 2 | 11.0 | 42 | 45 | 29.3 |
| to 4500 | T-4500 | 1 | 42" | 64 | 9 | 46 | 2 | 15.6 | 48 | 45 | 32.0 |
| | | | | | | | | | | | |
| **5000** | | | | | | | | | | | |
| to 5100 | T-5100 | 1 | 36" | 67 | 9.5 | 49 | 2 | 12.8 | 42 | 45 | 29.3 |
| to 5200 | T-5200 | 1 | 30" | 58 | 8 | 40 | 2 | 11.4 | 42 | 45 | 29.3 |
| to 5000.01 | P-5000.01 | | Pump-5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 5300 | T-5300 | 4 | 36" | 61 | 8.5 | 172 | 8 | 47.4 | 168 | 45 | 117.3 |
| to 5400 | T-5400 | 1 | 30" | 55 | 7.5 | 37 | 2 | 11.0 | 42 | 45 | 29.3 |
| to 5000.02 | P-5000.02 | | Pump-7.5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 5500 | T-5500 | 2 | 42" | 61 | 8.5 | 86 | 4 | 29.9 | 96 | 45 | 64.0 |
| | | | | | | | | | | | |
| **6000** | | | | | | | | | | | |
| to 6100 | T-6100 | 2 | 48" | 70 | 10 | 104 | 4 | 33.5 | 96 | 45 | 64.0 |
| to 6200 | T-6200 | 4 | 36" | 67 | 9.5 | 196 | 8 | 51.1 | 168 | 45 | 117.3 |
| to 6300 | T-6300 | 2 | 48" | 70 | 10 | 104 | 4 | 33.5 | 96 | 45 | 64.0 |
| to 6000.01 | P-6000.01 | | Pump-7.5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 6400 | T-6400 | 1 | 36" | 94 | 12 | 76 | 2 | 15.0 | 42 | 45 | 29.3 |
| to 6500 | T-6500 | 1 | 36" | 87 | 11 | 69 | 2 | 14.1 | 42 | 45 | 29.3 |
| to 6000.02 | P-6000.02 | | Pump-75hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 6000.03 | P-6000.03 | | Pump-5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 6600 | T-6600 | 1 | 48" | 61 | 8.5 | 43 | 2 | 15.0 | 48 | 45 | 32.0 |
| to 6000.04 | P-6000.04 | | Pump-50hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |
| to 6000.05 | P-6000.05 | | Pump-5hp | 50 | ------ | | | 13.9 | 36 | | 27.3 |

# Table IV-C-3
## Gate Well Structures
## Lateral Canal Turnout Quantities

| LATERAL CANAL TURNOUTS | | | | | QUANTITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Canal | Structure | Turnout | | | Pipe | End | Concrete | Grating | Riprap | Handrail |
| Number | Name | Diameter | Length (Ft.) | Height (Ft.) | Length (Ft.) | Sections | (cy) | (sf) | (tn) | (Ft) |
| **1500** | | | | | | | | | | |
| to 1510 | T-1510 | 18" | 40 | 5 | 22 | 2 | 8.0 | 36 | 45 | 27 |
| to 1500.01 | P-1500.01 | Pump-6hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 1500.02 | P-6000.02 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 1500.03 | P-6000.03 | Pump-10hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 1500.04 | P-6000.04 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 1520 | T-1520 | 18" | 31 | 3.5 | 13 | 2 | 6.7 | 36 | 45 | 27 |
| to 1500 | T-1500X | 18" | 31 | 3.5 | 13 | 2 | 6.7 | 36 | 45 | 27 |
| | | | | | | | | | | |
| **1520** | | | | | | | | | | |
| to 1520.01 | P-1520.01 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 1520.02 | P-1520.02 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 1520 | T-1520X | 18" | 31 | 3.5 | 13 | 2 | 6.7 | 36 | 45 | 27 |
| | | | | | | | | | | |
| **2200** | | | | | | | | | | |
| to 2200.01 | P-2200.01 | Pump-60hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 2200.02 | P-2200.02 | Pump-95hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 2210 | T-2210 | 48" | 61 | 8.5 | 43 | 2 | 15.0 | 48 | 45 | 32 |
| to 2200.03 | P-2200.03 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 2200.04 | P-2200.04 | Pump-10hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 2220 | T-2220 | 18" | 43 | 5.5 | 25 | 2 | 8.4 | 36 | 45 | 27 |
| to 2230 | T-2230 | 48" | 70 | 10 | 104 | 4 | 33.5 | 96 | 45 | 64 |
| to 2240 | T-2240 | 24" | 37 | 4.5 | 38 | 4 | 15.1 | 72 | 45 | 55 |
| to 2250 | T-2250 | 18" | 37 | 4.5 | 19 | 2 | 7.5 | 36 | 45 | 27 |
| to 2260 | T-2260 | 18" | 37 | 4.5 | 19 | 2 | 7.5 | 36 | 45 | 27 |
| to 2200.05 | P-2200.05 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 2200 | T-2200X | 48" | 55 | 7.5 | 37 | 2 | 13.8 | 48 | 45 | 32 |
| | | | | | | | | | | |
| **2230** | | | | | | | | | | |
| | | | | | | | | | | |
| to 2230.01 | P-2230.01 | Pump-8hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 2230 | T-2230X | 48" | 70 | 10 | 104 | 4 | 33.5 | 96 | 45 | 64 |

**Table IV-C-3**
**Gate Well Structures**
**Lateral Canal Turnout Quantities**

| LATERAL CANAL TURNOUTS | | | | | QUANTITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Canal Number | Structure Name | Turnout Diameter | Turnout Length (Ft.) | Turnout Height (Ft.) | Pipe Length (Ft.) | End Sections | Concrete (cy) | Grating (sf) | Riprap (tn) | Handrail (Ft) |
| | | | | | | | | | | |
| **2240** | | | | | | | | | | |
| to 2240 | T-2240X | 24" | 70 | 10 | 104 | 4 | 24.4 | 72 | 45 | 55 |
| **2400** | | | | | | | | | | |
| to 2410 | T-2410 | 30" | 43 | 5.5 | 25 | 2 | 9.1 | 42 | 45 | 29 |
| to 2400.01 | P-2400.01 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| | | | | | | | | | | |
| **3100** | | | | | | | | | | |
| to 3100.01 | P-3100.01 | Pump-7.5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 3100.02 | P-3100.02 | Pump-7.5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 3100 | T-3100X | 24" | 37 | 4.5 | 19 | 2 | 7.5 | 36 | 45 | 27 |
| | | | | | | | | | | |
| **3200** | | | | | | | | | | |
| to 3210 | T-3210 | 18" | 55 | 7.5 | 37 | 2 | 10.1 | 36 | 45 | 27 |
| to 3220 | T-3220 | 30" | 64 | 9 | 46 | 2 | 12.3 | 42 | 45 | 29 |
| to 3230 | T-3230 | 18" | 55 | 7.5 | 37 | 2 | 10.1 | 36 | 45 | 27 |
| to 3200.01 | P-3200.01 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 3240 | T-3240 | 18" | 49 | 6.5 | 31 | 2 | 9.2 | 36 | 45 | 27 |
| to 3250 | P-3250 | Pump-10hp | 46 | 6 | | | 13.9 | 36 | | 27 |
| to 3260 | T-3260 | 30" | 55 | 7.5 | 37 | 2 | 11.0 | 42 | 45 | 29 |
| to 3200.02 | P-3200.02 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 3200.03 | P-3200.03 | Pump-7.5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 3200.04 | P-3200.04 | Pump-15hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 3200 | T-3200X | 24" | 43 | 5.5 | 25 | 2 | 8.4 | 36 | 45 | 27 |
| | | | | | | | | | | |
| **3220** | | | | | | | | | | |
| to 3221 | T-3221 | 24" | 31 | 3.5 | 13 | 2 | 6.7 | 36 | 45 | 27 |
| to 3222 | T-3222 | 18" | 34 | 4 | 16 | 2 | 7.1 | 36 | 45 | 27 |
| to 3220 | T-3220X | 30" | 40 | 5 | 22 | 2 | 8.7 | 42 | 45 | 29 |
| | | | | | | | | | | |
| **3300** | | | | | | | | | | |
| to 3300.01 | P-3300.01 | Pump-10hp | 40 | ------ | | | 13.9 | 36 | | 27 |

# Table IV-C-3
## Gate Well Structures
## Lateral Canal Turnout Quantities

| LATERAL CANAL TURNOUTS | | | | | QUANTITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Canal Number | Structure Name | Turnout Diameter | Turnout Length (Ft.) | Turnout Height (Ft.) | Pipe Length (Ft.) | End Sections | Concrete (cy) | Grating (sf) | Riprap (tn) | Handrail (Ft) |
| to 3300 | T-3300X | 24" | 37 | 4.5 | 19 | 2 | 7.5 | 36 | 45 | 27 |
| | | | | | | | | | | |
| **3400** | | | | | | | | | | |
| to 3400 | T-3400X | 30" | 70 | 10 | 52 | 2 | 13.2 | 42 | 45 | 29 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| **3500A** | | | | | | | | | | |
| to 3500.01 | P-3500.01 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 3510 | T-3510 | 24" | 40 | 5 | 22 | 2 | 8.0 | 36 | 45 | 27 |
| | | | | | | | | | | |
| **4100** | | | | | | | | | | |
| to 4100.01 | P-4100.01 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 4100 | T-4100X | 48" | 70 | 10 | 104 | 4 | 33.5 | 96 | 45 | 64 |
| | | | | | | | | | | |
| **4200** | | | | | | | | | | |
| to 4200.01 | P-4200.01 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 4200.02 | P-4200.02 | Pump-7.5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 4200 | T-4200X | 30" | 70 | 10 | 52 | 2 | 13.2 | 42 | 45 | 29 |
| | | | | | | | | | | |
| **4500** | | | | | | | | | | |
| to 4510 | T-4510 | 24" | 55 | 7.5 | 37 | 2 | 10.1 | 36 | 45 | 27 |
| to 4520 | T-4520 | 24" | 37 | 4.5 | 19 | 2 | 7.5 | 36 | 45 | 27 |
| to 4500.01 | P-4500.01 | Pump-10hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 4500.02 | P-4500.02 | Pump-7.5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 4500.03 | T-4500.03 | 18" | 46 | 6 | 28 | 2 | 8.8 | 36 | 45 | 27 |
| | | | | | | | | | | |
| **5300** | | | | | | | | | | |
| to 5310 | T-5310 | 42" | 55 | 7.5 | 37 | 2 | 13.8 | 48 | 45 | 32 |
| to 5300.03 | P-5300.03 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 5300 | T-5300X | 42" | 55 | 7.5 | 74 | 4 | 27.6 | 96 | 45 | 64 |
| | | | | | | | | | | |
| **5310** | | | | | | | | | | |

# Table IV-C-3
## Gate Well Structures
## Lateral Canal Turnout Quantities

| LATERAL CANAL TURNOUTS | | | | | QUANTITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Canal | Structure | Turnout | | | Pipe | End | Concrete | Grating | Riprap | Handrail |
| Number | Name | Diameter | Length (Ft.) | Height (Ft.) | Length (Ft.) | Sections | (cy) | (sf) | (tn) | (Ft) |
| to 5311 | T-5311 | | | | | | | | | |
| to 5310 | T-5310X | | | | | | | | | |
| | | | | | | | | | | |
| **5400** | | | | | | | | | | |
| to 5400.01 | P-5400.01 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 5400.02 | P-5400.02 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| **5500** | | | | | | | | | | |
| to 5510 | T-5510 | 24" | 52 | 7 | 34 | 2 | 9.7 | 36 | 45 | 27 |
| to 5500.02 | P-5500.02 | Pump-80hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 5500.03 | P-5500.03 | Pump-10hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 5500.04 | P-5500.04 | Pump-7.5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 5520 | T-5520 | 24" | 43 | 5.5 | 25 | 2 | 8.4 | 36 | 45 | 27 |
| to 5530 | T-5530 | 18" | 46 | 6 | 28 | 2 | 8.8 | 36 | 45 | 27 |
| to 5500.05 | P-5500.05 | Pump-7.5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 5500.06 | P-5500.06 | Pump-7.5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 5505 | T-5505 | 42" | 55 | 7.5 | 37 | 2 | 13.8 | 48 | 45 | 32 |
| | | | | | | | | | | |
| **6200** | | | | | | | | | | |
| to 6210 | T-6210 | 24" | 52 | 7 | 34 | 2 | 9.7 | 36 | 45 | 27 |
| to 6200.02 | P-6200.02 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 6215 | T-6215 | 42" | 58 | 8 | 40 | 2 | 14.4 | 48 | 45 | 32 |
| to 6200.03 | P-6200.03 | Pump-5hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 6200.04 | P-6200.04 | Pump-15hp | 40 | ------ | | | 13.9 | 36 | | 27 |
| to 6216 | T-6216 | 42" | 55 | 7.5 | 74 | 4 | 27.6 | 96 | 45 | 64 |
| to 6220 | T-6220 | 24" | 52 | 7 | 34 | 2 | 9.7 | 36 | 45 | 27 |
| to 6230 | T-6230 | 18" | 52 | 7 | 34 | 2 | 9.7 | 36 | 45 | 27 |
| to 6200.06 | P-6200.06 | 24" | 34 | 4 | 16 | 2 | 7.1 | 36 | 45 | 27 |
| to 6100 | T-6230X | 24" | 34 | 4 | 16 | 2 | 7.1 | 36 | 45 | 27 |
| | | | | | | | | | | |

# Table IV-C-3
# Gate Well Structures
# Lateral Canal Turnout Quantities

| LATERAL CANAL TURNOUTS | | | | | QUANTITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Canal | Structure | Turnout | | | Pipe | End | Concrete | Grating | Riprap | Handrail |
| Number | Name | Diameter | Length (Ft.) | Height (Ft.) | Length (Ft.) | Sections | (cy) | (sf) | (tn) | (Ft) |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| **6600** | | | | | | | | | | |
| to 6300 | T-6300X | 24" | 34 | 4 | 16 | 2 | 7.1 | 36 | 45 | 27 |
| to 6610 | T-6310 | 24" | 34 | 4 | 16 | 2 | 7.1 | 36 | 45 | 27 |
| to 6600.01 | P-6600.01 | Pump-7.5 | | ------ | | | 13.9 | 36 | | 27 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

## Table IV-C-4
## Gate Well Structures
## Watseway Quantities

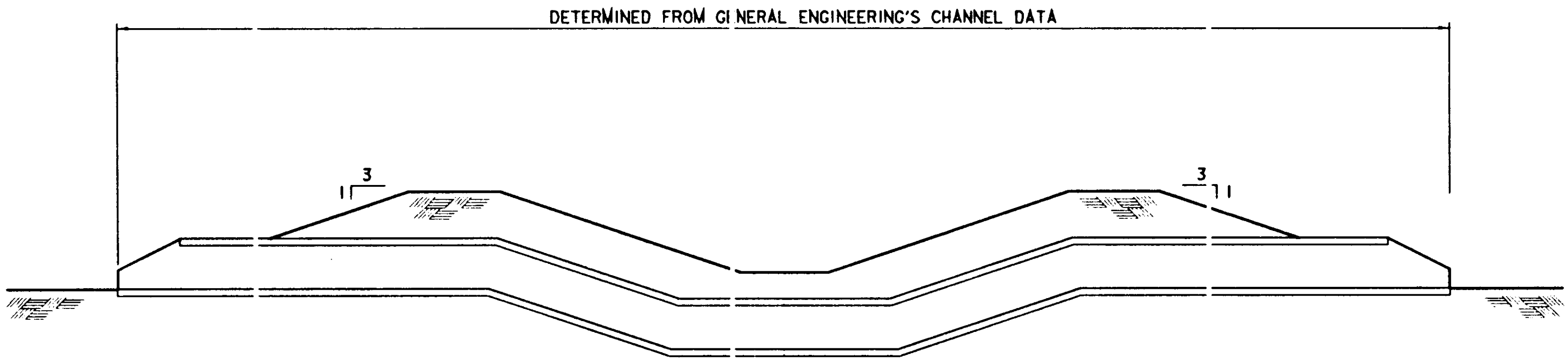
| WASTEWAYS | | | | | | QUANTITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Canal | Structure | Pipe | Turnout | | | Pipe | End | Concrete | Grating | 12" Gabion | Handrail |
| Number | Name | Runs | Diameter | Length (Ft.) | Height (Ft.) | Length (Ft.) | Sections | (cy) | (sf) | (sf) | (Ft) |
| | | | | | | | | | | | |
| 2000 | WW2000.01 | 3 | 42" | 104.5 | 13.5 | 260 | 6 | 62.7 | 144 | 3900 | 96 |
| 3000 | WW3000.01 | 1 | 42" | 104.5 | 13.5 | 87 | 2 | 20.9 | 48 | 3900 | 32 |
| 4000 | WW4000.01 | 1 | 48" | 104.5 | 13.5 | 87 | 2 | 20.9 | 48 | 3900 | 32 |
| 5000 | WW5000.01 | 2 | 48" | 104.5 | 13.5 | 173 | 4 | 41.8 | 96 | 3900 | 64 |
| 6000 | WW6000.01 | 3 | 48" | 104.5 | 13.5 | 260 | 6 | 62.7 | 144 | 3900 | 96 |
| 6000 | WW6000.02 | 1 | 48" | 104.5 | 13.5 | 87 | 2 | 20.9 | 48 | 3900 | 32 |
| 6000 | WW6000.03 | 1 | 36" | 104.5 | 13.5 | 86.5 | 2 | 16.4 | 42 | 3900 | 29 |
| | | | | | | | | | | | |

# Grand Prairie Area Demonstration Project
## Structural, Electrical & Mechanical

# APPENDIX IV-D

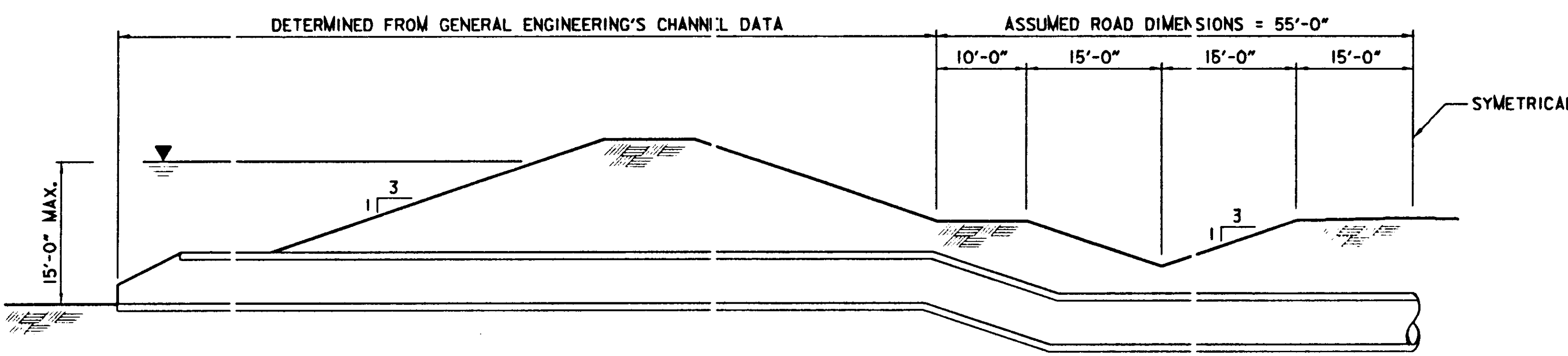
# CROSSINGS

U.S. Army Corps of Engineers
Memphis District




## TYPICAL CANAL CROSSING

N.T.S.




## TYPICAL ROAD CROSSING

N.T.S.

US Army Corps of Engineers

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

# INVERTED PIPE SIPHONS

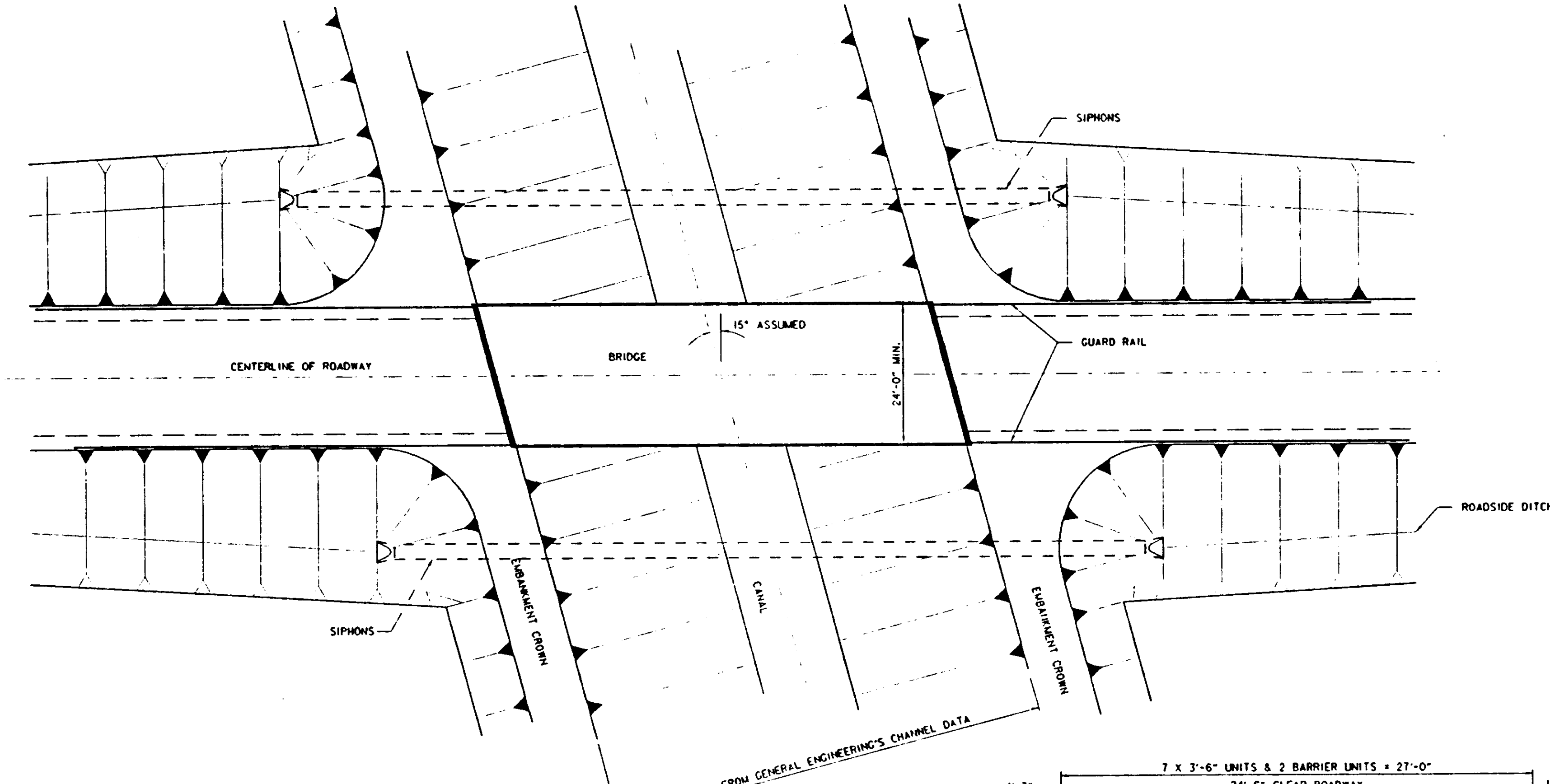
PLATE
IV-D-1

US Army Corps of Engineers

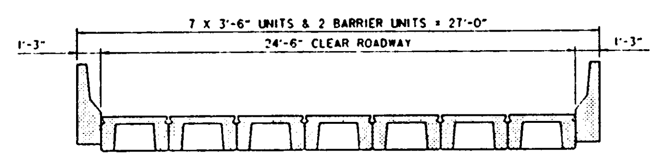
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

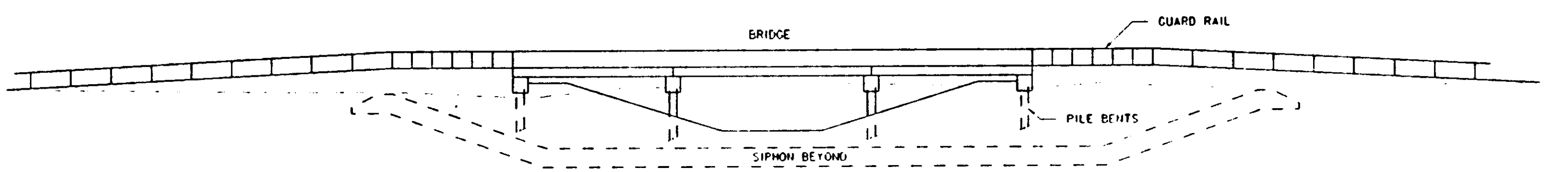
# Typical Bridge Layout




**TYPICAL SITE LAYOUT**
N.T.S.




**TYPICAL BRIDGE DECK**
N.T.S.




**CENTERLINE PROFILE**
N.T.S.

PLATE
IV-D-3

# Table IV-D-1
## Crossings
## Road - Quantities

| CANAL NUMBER | GENERAL DESCRIPTION | NUMBER PIPE RUNS | LENGTH (ft) | PIPE DIA. (ft) | BOX HEIGHT (ft) | BOX/BRDG WIDTH (ft) | SPECIAL NOTES | Excavation (cy) | Bedding (cy) | Concrete (cy) | Backfill (cy) | Roadway 8" Base (cy) | 4" Asphalt (cy) | Seeding (sf) | Flared End Section (ea) | Angled Sections (ea) | Pipe Length (ft) | Pipe Bedding (cy) | Pipe Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1000-1 | Deleted 12/16/96 MSW | | | | | | | | | | | | | | | | | | |
| 1000-3 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 1000-5 | US 70 | 7 | 290 | | 8 | 10 | CULVERT | 28158 | 838 | 2607 | 18942 | 246 | 123 | 113422 | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 2000-1 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 2000-1A | Deleted 12/16/96 MSW | | | | | | | | | | | | | | | | | | |
| 2000-2 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 2000-2B | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 2000-3 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 2000-4 | SR 11 | 7 | 290 | | 8 | 10 | CULVERT | 28158 | 838 | 2607 | 18942 | 246 | 123 | 113422 | | | | | |
| 2000-5 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 2000-6 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 2000-7 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 3000-1 | CO. RD. | | 175 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 3000-2 | Hazen Airfield Rd. | | 205 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 3000-4 | CO. RD. | | 205 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 3000-5 | SR 86 | 5 | 290 | | 8 | 10 | CULVERT | 23030 | 601 | 1896 | 16414 | 231 | 116 | 97289 | | | | | |
| 3000-6 | CO. RD. | | 187 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 3000-7 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 3000-10 | Deleted 12/16/96 MSW | | | | | | | | | | | | | | | | | | |
| 3000-11 | SR. 86 | 5 | 290 | | 8 | 10 | CULVERT | 23030 | 601 | 1896 | 16414 | 231 | 116 | 97289 | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 4000-2 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 4000-3 | SR 86 | 5 | 290 | | 8 | 10 | CULVERT | 23030 | 601 | 1896 | 16414 | 231 | 116 | 97289 | | | | | |
| 4000-4 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 4000-6 | CO. RD. | | 187 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 4000-7 | CO. RD. | | 187 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 4000-8 | CO. RD. | | 187 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 4000-10 | CO. RD. | | 187 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 4000-11 | CO. RD. | | 187 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 4000-12 | CO. RD. | | 187 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 4000-13 | CO. RD. Deleted 12/16/96 Jen | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 5000-1A | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 5000-1 | SR. 11 | 5 | 300 | | 8 | 10 | CULVERT | 23700 | 622 | 1956 | 16855 | 231 | 116 | 99942 | | | | | |
| 5000-3 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 5000-5 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 5000-6 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 5000-6A | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 6000-1 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 6000-2 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 6000-3 or 4 | US 79 & St. Louis & SouthwesternR/R | 4 | 260 | | 8 | 10 | CULVERTPARTOF 45.53 | 18691 | 433 | 1396 | 13925 | 223 | 112 | 81922 | | | | | |
| 6000-5 | SR 146 | 4 | 260 | | 8 | 10 | CULVERT | 18691 | 433 | 1396 | 13925 | 223 | 112 | 81922 | | | | | |
| 6000-5A | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 6000-5B | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 6000-6 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 6000-8 | Changed to bridge 12/16/96 MSW | | | | | 28 | BRIDGE | | | | | | | | | | | | |
| 6000-9 | SR 11/130 | 3 | 260 | 8 | | | CULVERT | | | | | 198 | 99 | 43940 | 6 | 12 | 696 | 1066 | III |
| 6000-9A | FIELD RD. | | | | | | | | | | | | | | | | | | |
| 6000-10 | St. Louis & SouthwesternR/R(abandoned) | 3 | 260 | 8 | | | CULVERT | | | | | 198 | 99 | 43940 | 6 | 12 | 696 | 1066 | III |
| 6000-11 | CO. RD. | 3 | 260 | 8 | | | CULVERT | | | | | 198 | 99 | 43940 | 6 | 12 | 696 | 1066 | III |
| 6000-11A | FIELD RD. | | | | | | | | | | | | | | | | | | |
| 6000-12 | CO. RD. | | 143 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 6000-14 | CO. RD. | | 143 | | | 28 | BRIDGE | | | | | | | | | | | | |
| 6000-15 | FIELD RD. | 3 | 260 | 8 | | | CULVERT | | | | | 198 | 99 | 43940 | 6 | 12 | 696 | 1066 | III |
| 6000-16 | FIELD RD. | 3 | 260 | 8 | | | CULVERT | | | | | 198 | 99 | 43940 | 6 | 12 | 696 | 1066 | III |
| 6000-17 | CO. RD. | 3 | 260 | 8 | | | CULVERT | | | | | 198 | 99 | 43940 | 6 | 12 | 696 | 1066 | III |
| 6000-18 | CO. RD. | 3 | 260 | 8 | | | CULVERT | | | | | 198 | 99 | 43940 | 6 | 12 | 696 | 1066 | III |
| 6000-18A | | | | | | | | | | | | | | | | | | | |
| 6000-18B | CO. RD. | 3 | 260 | 8 | | | CULVERT | | | | | 198 | 99 | 43940 | 6 | 12 | 696 | 1066 | III |
| 6000-C | | | | | | | | | | | | | | | | | | | |

# Table IV-D-1
## Crossings
## Road - Quantities

| CANAL NUMBER | GENERAL DESCRIPTION | NUMBER PIPE RUNS | LENGTH (ft) | PIPE DIA. (ft) | BOX HEIGHT (ft) | BOX/BRDG WIDTH (ft) | SPECIAL NOTES | Excavation (cy) | Bedding (cy) | Concrete (cy) | Backfill (cy) | Roadway 8" Base (cy) | Roadway 4" Asphalt (cy) | Seeding (sf) | Flared End Section (ea) | Angled Sections (ea) | Pipe Length (ft) | Pipe Bedding (cy) | Pipe Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6000-19 | Deleted 10/10/96 MSW | 3 | 260 | 6 | | | CULVERT | | | | | 189 | 95 | 37700 | 6 | 12 | 696 | 681 | III |
| 6000-19B | CO. RD. | 3 | 260 | 6 | | | CULVERT | | | | | 189 | 95 | 37700 | 6 | 12 | 696 | 681 | III |
| 6000-20 | CO. RD. | 2 | 260 | 6 | | | CULVERT | | | | | 184 | 92 | 33540 | 4 | 8 | 464 | 471 | III |
| 6000-23 | CO. RD. | 2 | 260 | 6 | | | CULVERT | | | | | 184 | 92 | 33540 | 4 | 8 | 464 | 471 | III |
| 6000-25 | CO. RD. | 2 | 260 | 6 | | | CULVERT | | | | | 184 | 92 | 33540 | 4 | 8 | 464 | 471 | III |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 1500-1 | CO. RD. | 2 | 270 | 5 | | | CULVERT | | | | | 180 | 90 | 32130 | 4 | 8 | 484 | 376 | III |
| 1500-3 | CO. RD. | 2 | 270 | 5 | | | CULVERT | | | | | 180 | 90 | 32130 | 4 | 8 | 484 | 376 | III |
| 1500-4 | CO. RD. | 2 | 270 | 4 | | | CULVERT | | | | | 177 | 88 | 29430 | 4 | 8 | 484 | 277 | III |
| 1500-6 | SR 33 | 2 | 270 | 2 | | | CULVERT | | | | | 170 | 85 | 24030 | 4 | 8 | 484 | 124 | III |
| | | | | | | | | | | | | | | | | | | | |
| 1520-1 | CO. RD. | 1 | 200 | 2 | | | CULVERT | | | | | 167 | 84 | 16200 | 2 | 4 | 172 | 55 | III |
| | | | | | | | | | | | | | | | | | | | |
| 2200-1 | CO. RD. | 2 | 210 | 8 | | | CULVERT | | | | | 191 | 95 | 31290 | 4 | 8 | 364 | 592 | III |
| 2200-4 | CO. RD. | 2 | 210 | 8 | | | CULVERT | | | | | 191 | 95 | 31290 | 4 | 8 | 364 | 592 | III |
| 2200-5 | CO. RD. | 2 | 210 | 8 | | | CULVERT | | | | | 191 | 95 | 31290 | 4 | 8 | 364 | 592 | III |
| 2200-6 | CO. RD. | 2 | 210 | 8 | | | CULVERT | | | | | 191 | 95 | 31290 | 4 | 8 | 364 | 592 | III |
| 2200-8 | CO. RD. | 2 | 210 | 8 | | | CULVERT | | | | | 191 | 95 | 31290 | 4 | 8 | 364 | 592 | III |
| 2200-10 | CO. RD. | 2 | 210 | 7 | | | CULVERT | | | | | 187 | 94 | 29190 | 4 | 8 | 364 | 481 | III |
| 2200-11 | DRIVE | 2 | 210 | 7 | | | CULVERT | | | | | 187 | 94 | 29190 | 4 | 8 | 364 | 481 | III |
| 2200-12 | SR 86 | 2 | 210 | 7 | | | CULVERT | | | | | 187 | 94 | 29190 | 4 | 8 | 364 | 481 | III |
| 2200-14 | DR. | 2 | 210 | 7 | | | CULVERT | | | | | 187 | 94 | 29190 | 4 | 8 | 364 | 481 | III |
| 2200-15 | FIELD RD. | 2 | 210 | 7 | | | CULVERT | | | | | 187 | 94 | 29190 | 4 | 8 | 364 | 481 | III |
| 2200-16 | SR 86 (arbitrary) | 2 | 210 | 7 | | | CULVERT | | | | | 187 | 94 | 29190 | 4 | 8 | 364 | 481 | III |
| 2200-18 | FIELD RD. | 2 | 210 | 7 | | | CULVERT | | | | | 187 | 94 | 29190 | 4 | 8 | 364 | 481 | III |
| 2200-19 | DR. | 2 | 210 | 7 | | | CULVERT | | | | | 187 | 94 | 29190 | 4 | 8 | 364 | 481 | III |
| | | | | | | | | | | | | | | | | | | | |
| 2230-2 | | | | | | | PIPELINE | | | | | | | | | | | | |
| 2230-3 | | | | | | | PIPELINE | | | | | | | | | | | | |
| 2230-4 | | | | | | | PIPELINE | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 2240-1 | | | | | | | PIPLINE | | | | | | | | | | | | |
| 2240-2 | | | | | | | PIPELINE | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 2400-1 | CO. RD. | 2 | 210 | 4.5 | | | CULVERT | | | | | 179 | 89 | 23940 | 4 | 8 | 364 | 253 | III |
| 2400-4 | CO. RD. | 1 | 210 | 3 | | | CULVERT | | | | | 170 | 85 | 18690 | 2 | 4 | 182 | 88 | III |
| | | | | | | | | | | | | | | | | | | | |
| 2500-1 | CO. RD. | 2 | 210 | 2 | | | CULVERT | | | | | 170 | 85 | 18690 | 4 | 8 | 364 | 96 | III |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 3100-1 | CO. RD. | 1 | 230 | 3.5 | | | CULVERT | | | | | 171 | 86 | 21390 | 2 | 4 | 202 | 115 | III |
| 3100-2 | CO. RD. | 1 | 230 | 3 | | | CULVERT | | | | | 170 | 85 | 20470 | 2 | 4 | 202 | 96 | III |
| | | | | | | | | | | | | | | | | | | | |
| 3200-1 | US 70 | 2 | 280 | 8 | | | CULVERT | | | | | 191 | 95 | 41720 | 4 | 8 | 504 | 789 | III |
| 3200-4 | CO. RD. | 1 | 280 | 8 | | | CULVERT | | | | | 184 | 92 | 36120 | 2 | 4 | 252 | 431 | III |
| 3200-5 | CO. RD. | 1 | 280 | 7 | | | CULVERT | | | | | 181 | 90 | 33880 | 2 | 4 | 252 | 352 | III |
| 3200-6 | CO. RD. | 1 | 280 | 6.5 | | | CULVERT | | | | | 180 | 90 | 32760 | 2 | 4 | 252 | 316 | III |
| 3200-7 | CO. RD. | 1 | 280 | 6.5 | | | CULVERT | | | | | 180 | 90 | 32760 | 2 | 4 | 252 | 316 | III |
| 3200-8 | FIELD RD. | 1 | 280 | 6 | | | CULVERT | | | | | 178 | 89 | 31640 | 2 | 4 | 252 | 282 | III |
| 3200-9 | CO. RD. | 1 | 280 | 5 | | | CULVERT | | | | | 175 | 88 | 29400 | 2 | 4 | 252 | 219 | III |
| 3200-10 | CO. RD. | 1 | 280 | 5 | | | CULVERT | | | | | 175 | 88 | 29400 | 2 | 4 | 252 | 219 | III |
| 3200-11 | FIELD RD. | 1 | 280 | 4 | | | CULVERT | | | | | 173 | 86 | 27160 | 2 | 4 | 252 | 164 | III |
| | | | | | | | | | | | | | | | | | | | |
| 3220-1A | CO. RD. | 1 | 180 | 4 | | | CULVERT | | | | | 173 | 86 | 17460 | 2 | 4 | 152 | 106 | III |
| 3220-1B | US 70 | 1 | 180 | 4 | | | CULVERT | | | | | 173 | 86 | 17460 | 2 | 4 | 152 | 106 | III |
| 3220-1 | US 70 | 1 | 180 | 4 | | | CULVERT | | | | | 173 | 86 | 17460 | 2 | 4 | 152 | 106 | III |
| 3220-2 | CO. RD./HWY 249 | 1 | 180 | 4 | | | CULVERT | | | | | 173 | 86 | 17460 | 2 | 4 | 152 | 106 | III |
| 3220-3 | CO. RD./HWY 249 | 1 | 180 | 4 | | | CULVERT | | | | | 173 | 86 | 17460 | 2 | 4 | 152 | 106 | III |
| | | | | | | | | | | | | | | | | | | | |
| 3250-1 | CO. RD. | | | | | | PIPELINE | | | | | | | | | | | | |
| 3250-1A | | | | | | | PIPELINE | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |

# Table IV-D-1
# Crossings
# Road - Quantities

| CANAL NUMBER | GENERAL DESCRIPTION | NUMBER PIPE RUNS | LENGTH (ft) | PIPE DIA. (ft) | BOX HEIGHT (ft) | BOX/BRDG WIDTH (ft) | SPECIAL NOTES | Excavation (cy) | Bedding (cy) | Concrete (cy) | Backfill (cy) | Roadway 8" Base (cy) | Roadway 4" Asphalt (cy) | Seeding (sf) | Flared End Section (ea) | Angled Sections (ea) | Pipe Length (ft) | Pipe Bedding (cy) | Pipe Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ~~3300-1~~ | Deleted [illegible]/96 MSW | 2 | 230 | 3 | | | CULVERT | | | | | 173 | 87 | 22770 | 4 | 8 | 404 | 165 | III |
| 3300-2 | CO. RD. | 2 | 230 | 2.5 | | | CULVERT | | | | | 172 | 86 | 21620 | 4 | 8 | 404 | 134 | III |
| 3300-3 | CO. RD. | 2 | 230 | 1.5 | | | CULVERT | | | | | 168 | 84 | 19320 | 4 | 8 | 404 | 81 | III |
| | | | | | | | | | | | | | | | | | | | |
| 3400-1 | CO. RD. | | | | | | PIPELINE | | | | | | | | | | | | |
| 3400-2 | FIELD RD. | | | | | | PIPELINE | | | | | | | | | | | | |
| 3400-3 | CO. RD. | | | | | | PIPELINE | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 3500-1A | SR 86 | 2 | 220 | 5 | | | CULVERT | | | | | 180 | 90 | 26180 | 4 | 8 | 384 | 306 | III |
| 3500-1 | FIELD RD. | 2 | 220 | 5 | | | CULVERT | | | | | 180 | 90 | 26180 | 4 | 8 | 384 | 306 | III |
| 3500-3 | CO. RD. | 2 | 220 | 5 | | | CULVERT | | | | | 180 | 90 | 26180 | 4 | 8 | 384 | 306 | III |
| 3500-4 | DRIVE | 2 | 220 | 5 | | | CULVERT | | | | | 180 | 90 | 26180 | 4 | 8 | 384 | 306 | III |
| 3500-5 | CO. RD. | 2 | 220 | 4 | | | CULVERT | | | | | 177 | 88 | 23980 | 4 | 8 | 384 | 226 | III |
| 3500-6 | CO. RD. | 2 | 220 | 4 | | | CULVERT | | | | | 177 | 88 | 23980 | 4 | 8 | 384 | 226 | III |
| 3500A-1 | SR 86 | | | | | | PIPELINE | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 4100 -1A | SR 86 | 2 | 170 | 3 | | | CULVERT | | | | | 173 | 87 | 16830 | 4 | 8 | 284 | 122 | III |
| 4100-1 | LEVEE | 2 | 170 | 3 | | | CULVERT | | | | | 173 | 87 | 16830 | 4 | 8 | 284 | 122 | III |
| 4100-2 | CO. RD. | 2 | 170 | 3 | | | PIPELINE | | | | | 173 | 87 | 16830 | 4 | 8 | 284 | 122 | III |
| 4100-3 | SR 11 | 2 | 170 | 3 | | | PIPELINE | | | | | 173 | 87 | 16830 | 4 | 8 | 284 | 122 | III |
| 4200-1A | SR 46 | 2 | 200 | 4 | | | CULVERT | | | | | 177 | 88 | 21800 | 4 | 8 | 344 | 205 | III |
| 4200-1 | DR. | 2 | 200 | 4 | | | CULVERT | | | | | 177 | 88 | 21800 | 4 | 8 | 344 | 205 | III |
| 4200-2 | CO. RD. | 2 | 200 | 4 | | | CULVERT | | | | | 177 | 88 | 21800 | 4 | 8 | 344 | 205 | III |
| 4200-3 | LEVEE | 2 | 200 | 3.5 | | | CULVERT | | | | | 175 | 88 | 20800 | 4 | 8 | 344 | 173 | III |
| 4200-4 | FIELD RD. | 2 | 200 | 3.5 | | | CULVERT | | | | | 175 | 88 | 20800 | 4 | 8 | 344 | 173 | III |
| 4200-5 | SR 11 | 2 | 200 | 3.5 | | | CULVERT | | | | | 175 | 88 | 20800 | 4 | 8 | 344 | 173 | III |
| 4200-6 | St. Louis & SouthwesternR/R(abandoned) | 2 | 200 | 3 | | | CULVERT | | | | | 173 | 87 | 19800 | 4 | 8 | 344 | 143 | III |
| 4200-7 | CO. RD. | | | | | | PIPELINE | | | | | | | | | | | | |
| 4200-8 | DR. | | | | | | PIPELINE | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 4300-1 | SR 343 | | | | | | PIPELINE | | | | | | | | | | | | |
| 4300-2 | DR. | | | | | | PIPELINE | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 4400-1 | SR 343 | 2 | 200 | 2.5 | | | CULVERT | | | | | 172 | 86 | 18800 | 4 | 8 | 344 | 116 | III |
| 4400-2 | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 4500-1 | CO. RD. | 2 | 190 | 4 | | | CULVERT | | | | | 177 | 88 | 20710 | 4 | 8 | 324 | 195 | III |
| 4500-3 | SR 343 | 2 | 190 | 4 | | | CULVERT | | | | | 177 | 88 | 20710 | 4 | 8 | 324 | 195 | III |
| | | | | | | | | | | | | | | | | | | | |
| 4510-1 | DR. | | | | | | PIPELINE | | | | | | | | | | | | |
| 4510-2 | LEVEE | | | | | | PIPELINE | | | | | | | | | | | | |
| 4510-3 | SR 343 | | | | | | PIPELINE | | | | | | | | | | | | |
| 4510-4 | FIELD | | | | | | PIPELINE | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 4520-1 | CO. RD. | 1 | 210 | 3 | | | CULVERT | | | | | 170 | 85 | 18690 | 2 | 4 | 182 | 88 | III |
| | | | | | | | | | | | | | | | | | | | |
| 5200-1 | CO. RD. | 2 | 240 | 3 | | | CULVERT | | | | | 173 | 87 | 23760 | 4 | 8 | 424 | 172 | III |
| 5200-1A | CO. RD. | 2 | 240 | 3 | | | CULVERT | | | | | 173 | 87 | 23760 | 4 | 8 | 424 | 172 | III |
| 5200-3 | CO. RD. | 2 | 240 | 3 | | | CULVERT | | | | | 173 | 87 | 23760 | 4 | 8 | 424 | 172 | III |
| 5200-3A | CO. RD. | 2 | 240 | 3 | | | CULVERT | | | | | 173 | 87 | 23760 | 4 | 8 | 424 | 172 | III |
| 5200-4 | CO. RD. | 2 | 240 | 3 | | | PIPELINE | | | | | 173 | 87 | 23760 | 4 | 8 | 424 | 172 | III |
| 5200-5 | CO. RD. | 2 | 240 | 3 | | | CULVERT | | | | | 173 | 87 | 23760 | 4 | 8 | 424 | 172 | III |
| 5200-7 | CO. RD. | 2 | 240 | 3 | | | CULVERT | | | | | 173 | 87 | 23760 | 4 | 8 | 424 | 172 | III |
| | | | | | | | | | | | | | | | | | | | |
| 5300-1 | FIELD RD. | 2 | 220 | 7 | | | CULVERT | | | | | 187 | 94 | 30580 | 4 | 8 | 384 | 504 | III |
| 5300-3 | SR 11 | 2 | 220 | 7 | | | CULVERT | | | | | 187 | 94 | 30580 | 4 | 8 | 384 | 504 | III |
| 5300-4 | FIELD RD. | 2 | 220 | 6.5 | | | CULVERT | | | | | 186 | 93 | 29480 | 4 | 8 | 384 | 450 | III |
| 5300-5 | CO. RD. | 2 | 220 | 6.5 | | | CULVERT | | | | | 186 | 93 | 29480 | 4 | 8 | 384 | 450 | III |
| 5300-6 | CO. RD. | | | | | | PIPELINE | | | | | | | | | | | | |
| 5300-7 | FIELD RD. | | | | | | PIPELINE | | | | | | | | | | | | |
| 5300-8 | SR 130 | | | | | | PIPELINE | | | | | | | | | | | | |
| 5300-10 | CO. RD. | | | | | | PIPELINE | | | | | | | | | | | | |
| 5300-11 | CO. RD. | | | | | | PIPELINE | | | | | | | | | | | | |

**Table IV-D-1**
**Crossings**
**Road - Quantities**

| CANAL NUMBER | GENERAL DESCRIPTION | NUMBER PIPE RUNS | LENGTH (ft) | PIPE DIA. (ft) | BOX HEIGHT (ft) | BOX/BRDG WIDTH (ft) | SPECIAL NOTES | Excavation (cy) | Bedding (cy) | Concrete (cy) | Backfill (cy) | Roadway 8" Base (cy) | Roadway 4" Asphalt (cy) | Seeding (sf) | Flared End Section (ea) | Angled Sections (ea) | Pipe Length (ft) | Pipe Bedding (cy) | Pipe Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | Deleted 12/16/96 MSW | | | | | | PIPELINE | | | | | | | | | | | | |
| 5300-12 | DR. | 2 | 220 | 6 | | | CULVERT | | | | | 184 | 92 | 28380 | 4 | 8 | 384 | 399 | III |
| 5300-13 | CO. RD. | 2 | 220 | 6 | | | CULVERT | | | | | 184 | 92 | 28380 | 4 | 8 | 384 | 399 | III |
| 5300-14 | CO. RD. | 2 | 220 | 6 | | | CULVERT | | | | | 184 | 92 | 28380 | 4 | 8 | 384 | 399 | III |
| | | | | | | | | | | | | | | | | | | | |
| 5310-3 | CO. RD. | 2 | 220 | 5 | | | PIPELINE | | | | | 180 | 90 | 26180 | 4 | 8 | 384 | 306 | III |
| | | | | | | | | | | | | | | | | | | | |
| 5400-1 | CO. RD. | 2 | 180 | 3 | | | CULVERT | | | | | 173 | 87 | 17820 | 4 | 8 | 304 | 129 | III |
| 5400-2 | FIELD RD. | 2 | 180 | 3 | | | CULVERT | | | | | 173 | 87 | 17820 | 4 | 8 | 304 | 129 | III |
| 5400-3 | CO. RD. | 2 | 180 | 2.5 | | | CULVERT | | | | | 172 | 86 | 16920 | 4 | 8 | 304 | 105 | III |
| | | | | | | | | | | | | | | | | | | | |
| 5500-1A | CO. RD. | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-1B | CO. RD. | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-1 | CO. RD. | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-2 | US 79 | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-2 | St. Louis & SouthwesternR/R | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-3 | CO. RD. | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-4A | CO. RD. | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-5 | CO. RD. | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-6 | CO. RD. | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-8 | DR. | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-8A | FIELD RD. | 2 | 180 | 6 | | | CULVERT | | | | | 184 | 92 | 23220 | 4 | 8 | 304 | 326 | III |
| 5500-9 | CO. RD. | 2 | 180 | 5 | | | CULVERT | | | | | 180 | 90 | 21420 | 4 | 8 | 304 | 251 | III |
| 5500-10 | CO. RD. | 2 | 180 | 5 | | | CULVERT | | | | | 180 | 90 | 21420 | 4 | 8 | 304 | 251 | III |
| 5500-11 | CO. RD. | 2 | 180 | 5 | | | CULVERT | | | | | 180 | 90 | 21420 | 4 | 8 | 304 | 251 | III |
| 5500-12 | CO. RD. | 1 | 180 | 5 | | | CULVERT | | | | | 175 | 88 | 18900 | 2 | 4 | 152 | 141 | III |
| 5500-13 | DR. | 1 | 180 | 5 | | | CULVERT | | | | | 175 | 88 | 18900 | 2 | 4 | 152 | 141 | III |
| 5500-14 | CO. RD. | 1 | 180 | 5 | | | CULVERT | | | | | 175 | 88 | 18900 | 2 | 4 | 152 | 141 | III |
| 5500-15 | CO. RD. | 1 | 180 | 4 | | | CULVERT | | | | | 173 | 86 | 17460 | 2 | 4 | 152 | 106 | III |
| 5500-16 | CO. RD. | 1 | 180 | 4 | | | CULVERT | | | | | 173 | 86 | 17460 | 2 | 4 | 152 | 106 | III |
| | | | | | | | | | | | | | | | | | | | |
| 6200-1 | CO. RD. | 1 | 240 | | 10 | 10 | CULVERT | 13431 | 107 | 440 | 12044 | 206 | 103 | 62769 | | | | | |
| 6200-3 | CO. RD. | 1 | 240 | | 10 | 10 | CULVERT | 13431 | 107 | 440 | 12044 | 206 | 103 | 62769 | | | | | |
| 6200-4 | CO. RD. | 1 | 240 | | 10 | 10 | CULVERT | 13431 | 107 | 440 | 12044 | 206 | 103 | 62769 | | | | | |
| 6200-6 | CO. RD. | 1 | 240 | | 9 | 9 | CULVERT | 11728 | 96 | 364 | 10589 | 202 | 101 | 58133 | | | | | |
| 6200-7 | CO. RD. | 1 | 240 | | 9 | 9 | CULVERT | 11728 | 96 | 364 | 10589 | 202 | 101 | 58133 | | | | | |
| 6200-8 | CO. RD. | 1 | 240 | | 8 | 8 | CULVERT | 10157 | 86 | 294 | 9241 | 198 | 99 | 53607 | | | | | |
| 6200-12 | CO. RD. | 1 | 240 | | 8 | 8 | CULVERT | 10157 | 86 | 294 | 9241 | 198 | 99 | 53607 | | | | | |
| 6200-13 | CO. RD. | 1 | 240 | | 8 | 8 | CULVERT | 10157 | 86 | 294 | 9241 | 198 | 99 | 53607 | | | | | |
| 6200-14 | CO. RD. | 1 | 240 | | 8 | 8 | CULVERT | 10157 | 86 | 294 | 9241 | 198 | 99 | 53607 | | | | | |
| 6200-17 | CO. RD. | 1 | 240 | | 8 | 8 | CULVERT | 10157 | 86 | 294 | 9241 | 198 | 99 | 53607 | | | | | |
| 6200-18 | St. Louis & SouthwesternR/R(abandoned) | 1 | 240 | | 8 | 8 | CULVERT | 10157 | 86 | 294 | 9241 | 198 | 99 | 53607 | | | | | |
| 6200-19 | CO. RD. | 1 | 240 | | 8 | 8 | CULVERT | 10157 | 86 | 294 | 9241 | 198 | 99 | 53607 | | | | | |
| 6200-20 | CO. RD. | 1 | 240 | | 8 | 8 | CULVERT | 10157 | 86 | 294 | 9241 | 198 | 99 | 53607 | | | | | |
| 6200-21 | CO. RD. | 1 | 240 | | 8 | 8 | CULVERT | 10157 | 86 | 294 | 9241 | 198 | 99 | 53607 | | | | | |
| 6200-22 | CO. RD. | 1 | 240 | | 8 | 8 | CULVERT | 10157 | 86 | 294 | 9241 | 198 | 99 | 53607 | | | | | |
| 6200-24 | CO. RD. Deleted 12/16/96 Jan | 1 | 240 | | 7 | 7 | CULVERT | | | | | | | | | | | | |
| 6200-26 | FIELD RD. | 1 | 240 | | 7 | 7 | CULVERT | 8714 | 76 | 233 | 7996 | 194 | 97 | 49189 | | | | | |
| 6200-27 | CO. RD. | 1 | 240 | 5 | | | CULVERT | | | | | 175 | 88 | 25200 | 2 | 4 | 212 | 188 | III |
| 6200-28 | DR. | 1 | 240 | 4.5 | | | CULVERT | | | | | 174 | 87 | 24240 | 2 | 4 | 212 | 164 | III |
| 6200-29 | CO. RD. | 1 | 240 | 4.5 | | | CULVERT | | | | | 174 | 87 | 24240 | 2 | 4 | 212 | 164 | III |
| 6200-30 | CO. RD. | 1 | 240 | 4.5 | | | CULVERT | | | | | 174 | 87 | 24240 | 2 | 4 | 212 | 164 | III |
| 6200-31 | CO. RD./RR | 1 | 240 | 4.5 | | | CULVERT | | | | | 174 | 87 | 24240 | 2 | 4 | 212 | 164 | III |
| 6200-32 | FIELD RD. | 1 | 240 | 4.5 | | | CULVERT | | | | | 174 | 87 | 24240 | 2 | 4 | 212 | 164 | III |
| 6200-33 | CO. RD. | 1 | 240 | 4.5 | | | CULVERT | | | | | 174 | 87 | 24240 | 2 | 4 | 212 | 164 | III |
| 6200-35 | CO. RD. | 1 | 240 | 4.5 | | | CULVERT | | | | | 174 | 87 | 24240 | 2 | 4 | 212 | 164 | III |
| 6200-36 | DR. | 1 | 240 | 4.5 | | | CULVERT | | | | | 174 | 87 | 24240 | 2 | 4 | 212 | 164 | III |
| | | | | | | | | | | | | | | | | | | | |
| 6400-1 | CO. RD. | 2 | 250 | 4.5 | | | CULVERT | | | | | 179 | 89 | 28500 | 4 | 8 | 444 | 301 | III |
| 6400-1B | FIELD RD. | 2 | 250 | 3.5 | | | CULVERT | | | | | 175 | 88 | 26000 | 4 | 8 | 444 | 216 | III |
| 6400-2 | SR165 | 2 | 250 | 3.5 | | | CULVERT | | | | | 175 | 88 | 26000 | 4 | 8 | 444 | 216 | III |
| 6400-3 | CO. RD. | 2 | 250 | 2.5 | | | CULVERT | | | | | 172 | 86 | 23500 | 4 | 8 | 444 | 145 | III |
| 6400-4 | CO. RD. | 2 | 250 | 2.5 | | | CULVERT | | | | | 172 | 86 | 23500 | 4 | 8 | 444 | 145 | III |

# Table IV-D-1
## Crossings
## Road - Quantities

| CANAL NUMBER | GENERAL DESCRIPTION | NUMBER PIPE RUNS | LENGTH (ft) | PIPE DIA. (ft) | BOX HEIGHT (ft) | BOX/BRDG WIDTH (ft) | SPECIAL NOTES | Excavation (cy) | Bedding (cy) | Concrete (cy) | Backfill (cy) | Roadway 8" Base (cy) | Roadway 4" Asphalt (cy) | Seeding (sf) | Flared End Section (ea) | Angled Sections (ea) | Pipe Length (ft) | Pipe Bedding (cy) | Pipe Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ~~6600-1~~ | Deleted 10/10/96 MSW | ~~2~~ | ~~250~~ | ~~2.5~~ | | | ~~CULVERT~~ | | | | | ~~172~~ | ~~86~~ | ~~23500~~ | ~~4~~ | ~~8~~ | ~~444~~ | ~~145~~ | ~~III~~ |
| | | | | | | | | | | | | | | | | | | | |
| 6600-4 | FIELD RD. | 2 | 190 | 6 | | | CULVERT | | | | | 184 | 92 | 24510 | 4 | 8 | 324 | 345 | III |
| 6600-5 | DR. | 2 | 190 | 6 | | | CULVERT | | | | | 184 | 92 | 24510 | 4 | 8 | 324 | 345 | III |
| 6600-7 | CO. RD. | 2 | 190 | 5 | | | CULVERT | | | | | 180 | 90 | 22610 | 4 | 8 | 324 | 265 | III |
| 6600-9 | FIELD RD. | 2 | 190 | 5 | | | CULVERT | | | | | 180 | 90 | 22610 | 4 | 8 | 324 | 265 | III |
| 6600-9A | CO. RD. | 2 | 190 | 5 | | | CULVERT | | | | | 180 | 90 | 22610 | 4 | 8 | 324 | 265 | III |
| 6600-11 | CO. RD. | 2 | 190 | 4 | | | CULVERT | | | | | 177 | 88 | 20710 | 4 | 8 | 324 | 195 | III |
| 6600-13 | CO. RD. | 2 | 190 | 4 | | | CULVERT | | | | | 177 | 88 | 20710 | 4 | 8 | 324 | 195 | III |
| 6600-14 | CO. RD. | 2 | 190 | 4 | | | CULVERT | | | | | 177 | 88 | 20710 | 4 | 8 | 324 | 195 | III |
| 6600-17 | FIELD RD. | 2 | 190 | 4 | | | CULVERT | | | | | 177 | 88 | 20710 | 4 | 8 | 324 | 195 | III |
| | | | | | | | | | | | | | | | | | | | |
| 6215-1 | | | | | | | PIPELINE | | | | | | | | | | | | |
| 6215-2 | | | | | | | PIPLINE | | | | | | | | | | | | |

## Table IV-D-2
## Crossings
## Canal Siphon - Quantities

| Canal No. | Siphon No. | Selected Siphon Diameter (in.) | Number of Siphons | Siphon Length (ft) | Pipe Length (ft) | Trench Depth (ft) | Trench Width (ft) | Flared End Section (ea) | Angled Sections (ea) | Pipe Bedding (cy) | Pipe Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1500 | 1 | 48 | 1 | 300 | 272 | 15 | 7 | 2 | 4 | 154 | III |
| 2200 | 1 | 78 | 1 | 300 | 272 | 18 | 10 | 2 | 4 | 307 | III |
| 2400 | 1 | 42 | 1 | 300 | 272 | 15 | 7 | 2 | 4 | 130 | III |
| 3100 | 1 | 42 | 1 | 300 | 272 | 15 | 7 | 2 | 4 | 130 | III |
| 3100 | 2 | 42 | 1 | 300 | 272 | 15 | 7 | 2 | 4 | 130 | III |
| 4000 | 8 | 96 | 5 | 300 | 1360 | 19 | 55 | 10 | 20 | 2114 | III |
| 5200 | 2 | 36 | 1 | 300 | 272 | 14 | 6 | 2 | 4 | 107 | III |
| 5200 | 4 | 36 | 1 | 300 | 272 | 14 | 6 | 2 | 4 | 107 | III |
| 6200 | 2 | 96 | 1 | 300 | 272 | 19 | 11 | 2 | 4 | 423 | III |
| 6200 | 3 | 96 | 1 | 300 | 272 | 19 | 11 | 2 | 4 | 423 | III |
| 6200 | 9 | 66 | 1 | 300 | 272 | 17 | 9 | 2 | 4 | 239 | III |
| 6600 | 4 | 60 | 1 | 300 | 272 | 16 | 8 | 2 | 4 | 209 | III |
| 6600 | 5 | 60 | 1 | 300 | 272 | 16 | 8 | 2 | 4 | 209 | III |

## Table IV-D-3
## Crossings
## Natural Drainage Siphon - Quantities

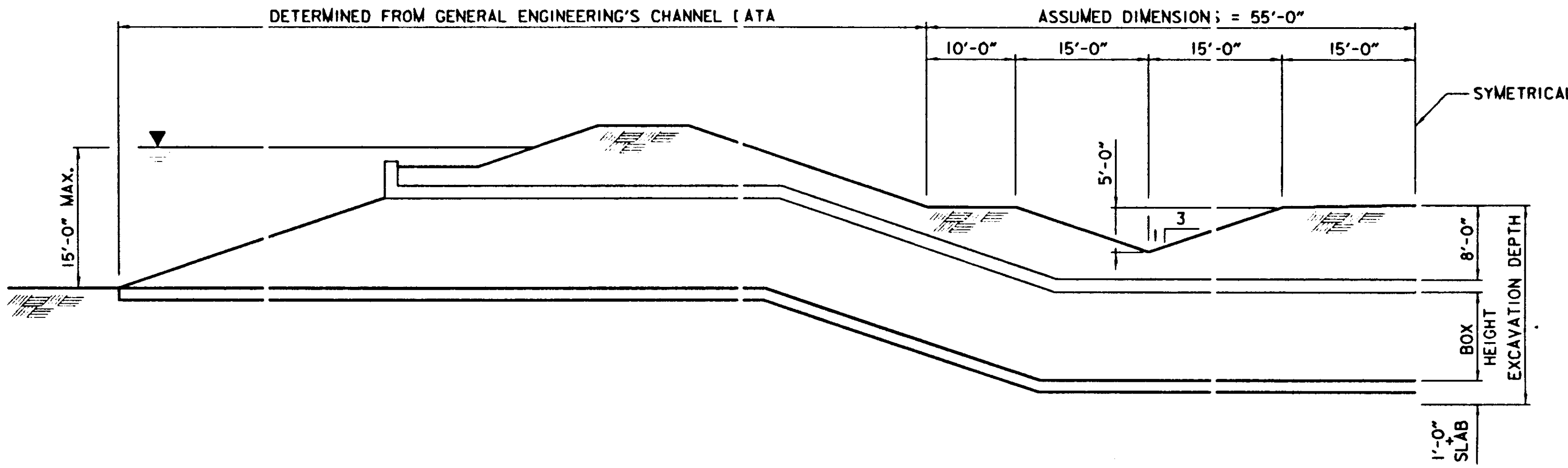
| Canal No. | Siphon No. | Selected Siphon Diameter (in.) | Number of Siphons | Siphon Length (ft) | Pipe Length (ft) | Trench Depth (ft) | Trench Width (ft) | Flared End Section (ea) | Angled Sections (ea) | Pipe Bedding (cy) | Pipe Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1000 | 1 | 42 | 1 | 240 | 212 | 15 | 7 | 2 | 4 | 104 | III |
| 1000 | 2 | 48 | 1 | 240 | 212 | 15 | 7 | 2 | 4 | 123 | III |
| 1000 | 3 | 48 | 1 | 240 | 212 | 15 | 7 | 2 | 4 | 123 | III |
| 1000 | 4 | 48 | 1 | 240 | 212 | 15 | 7 | 2 | 4 | 123 | III |
| 1500 | 2 | 60 | 1 | 170 | 142 | 16 | 8 | 2 | 4 | 118 | III |
| 1520 | 1 | 42 | 1 | 100 | 72 | 15 | 7 | 2 | 4 | 43 | III |
| 2000 | 1 | 66 | 1 | 240 | 212 | 17 | 9 | 2 | 4 | 192 | III |
| 2000 | 2 | 78 | 1 | 240 | 212 | 18 | 10 | 2 | 4 | 245 | III |
| 2000 | 3 | 72 | 1 | 240 | 212 | 17 | 9 | 2 | 4 | 218 | III |
| 2000 | 4 | 78 | 1 | 240 | 212 | 18 | 10 | 2 | 4 | 245 | III |
| 2000 | 5 | 54 | 1 | 240 | 212 | 16 | 8 | 2 | 4 | 144 | III |
| 2000 | 6 | 42 | 1 | 240 | 212 | 15 | 7 | 2 | 4 | 104 | III |
| 2200 | 2 | 60 | 1 | 120 | 92 | 16 | 8 | 2 | 4 | 84 | III |
| 2200 | 3 | 66 | 1 | 120 | 92 | 17 | 9 | 2 | 4 | 96 | III |
| 2200 | 4 | 66 | 1 | 120 | 92 | 17 | 9 | 2 | 4 | 96 | III |
| 2200 | 5 | 42 | 1 | 120 | 92 | 15 | 7 | 2 | 4 | 52 | III |
| 2200 | 6 | 60 | 1 | 120 | 92 | 16 | 8 | 2 | 4 | 84 | III |
| 2200 | 7 | 48 | 1 | 120 | 92 | 15 | 7 | 2 | 4 | 62 | III |
| 2200 | 8 | 66 | 1 | 120 | 92 | 17 | 9 | 2 | 4 | 96 | III |
| 3000 | 1 | 90 | 1 | 220 | 192 | 19 | 11 | 2 | 4 | 280 | III |
| 3000 | 3 | 42 | 1 | 220 | 192 | 15 | 7 | 2 | 4 | 95 | III |
| 3000 | 6 | 84 | 2 | 220 | 384 | 18 | 20 | 4 | 8 | 504 | III |
| 3000 | 7 | 78 | 2 | 220 | 384 | 18 | 19 | 4 | 8 | 450 | III |
| 3000 | 8 | 48 | 1 | 220 | 192 | 15 | 7 | 2 | 4 | 113 | III |
| 3000 | 9 | 30 | 1 | 220 | 192 | 14 | 6 | 2 | 4 | 64 | III |
| 3200 | 1 | 66 | 1 | 220 | 192 | 17 | 9 | 2 | 4 | 176 | III |
| 3200 | 2 | 54 | 1 | 220 | 192 | 16 | 8 | 2 | 4 | 132 | III |
| 3200 | 3 | 90 | 1 | 220 | 192 | 19 | 11 | 2 | 4 | 280 | III |
| 3220 | 1 | 36 | 1 | 220 | 192 | 14 | 6 | 2 | 4 | 79 | III |
| 3220 | 2 | 48 | 1 | 220 | 192 | 15 | 7 | 2 | 4 | 113 | III |
| 3300 | 1 | 78 | 2 | 130 | 204 | 18 | 19 | 4 | 8 | 266 | III |

## Table IV-D-3
## Crossings
## Natural Drainage Siphon - Quantities

| Canal No. | Siphon No. | Selected Siphon Diameter (in.) | Number of Siphons | Siphon Length (ft) | Pipe Length (ft) | Trench Depth (ft) | Trench Width (ft) | Flared End Section (ea) | Angled Sections (ea) | Pipe Bedding (cy) | Pipe Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3500 | 1 | 60 | 1 | 120 | 92 | 16 | 8 | 2 | 4 | 84 | III |
| 3500 | 2 | 90 | 1 | 120 | 92 | 19 | 11 | 2 | 4 | 153 | III |
| 3500 | 3 | 90 | 1 | 120 | 92 | 19 | 11 | 2 | 4 | 153 | III |
| 3500 | 5 | 84 | 1 | 120 | 92 | 18 | 10 | 2 | 4 | 137 | III |
| 4000 | 1 | 72 | 1 | 230 | 202 | 17 | 9 | 2 | 4 | 209 | III |
| 4000 | 2 | 42 | 1 | 230 | 202 | 15 | 7 | 2 | 4 | 99 | III |
| 4000 | 3 | 84 | 2 | 230 | 404 | 18 | 20 | 4 | 8 | 526 | III |
| 4000 | 5 | 48 | 1 | 230 | 202 | 15 | 7 | 2 | 4 | 118 | III |
| 4000 | 7 | 54 | 1 | 230 | 202 | 16 | 8 | 2 | 4 | 138 | III |
| 4200 | 1 | 84 | 2 | 100 | 144 | 18 | 20 | 4 | 8 | 229 | III |
| 4200 | 2 | 90 | 1 | 100 | 72 | 19 | 11 | 2 | 4 | 127 | III |
| 4500 | 1 | 96 | 1 | 90 | 62 | 19 | 11 | 2 | 4 | 127 | III |
| 4500 | 2 | 78 | 1 | 90 | 62 | 18 | 10 | 2 | 4 | 92 | III |
| 5000 | 1 | 42 | 1 | 240 | 212 | 15 | 7 | 2 | 4 | 104 | III |
| 5000 | 2 | 90 | 2 | 240 | 424 | 19 | 21 | 4 | 8 | 611 | III |
| 5000 | 3 | 90 | 1 | 240 | 212 | 19 | 11 | 2 | 4 | 306 | III |
| 5000 | 4 | 78 | 2 | 240 | 424 | 18 | 19 | 4 | 8 | 491 | III |
| 5000 | 5 | 48 | 1 | 240 | 212 | 15 | 7 | 2 | 4 | 123 | III |
| 5200 | 6 | 90 | 1 | 180 | 152 | 19 | 11 | 2 | 4 | 229 | III |
| 5200 | 7 | 48 | 1 | 180 | 152 | 15 | 7 | 2 | 4 | 92 | III |
| 5400 | 1 | 96 | 1 | 80 | 52 | 19 | 11 | 2 | 4 | 113 | III |
| 5500 | 2 | 84 | 3 | 90 | 186 | 18 | 30 | 6 | 12 | 309 | III |
| 5500 | 4 | 60 | 1 | 90 | 62 | 16 | 8 | 2 | 4 | 63 | III |
| 5500 | 5 | 54 | 1 | 90 | 62 | 16 | 8 | 2 | 4 | 54 | III |
| 5500 | 6 | 60 | 1 | 90 | 62 | 16 | 8 | 2 | 4 | 63 | III |
| 5500 | 7 | 54 | 1 | 90 | 62 | 16 | 8 | 2 | 4 | 54 | III |
| 5500 | 8 | 96 | 1 | 90 | 62 | 19 | 11 | 2 | 4 | 127 | III |
| 5500 | 9 | 84 | 2 | 90 | 124 | 18 | 20 | 4 | 8 | 206 | III |
| 5500 | 10 | 66 | 1 | 90 | 62 | 17 | 9 | 2 | 4 | 72 | III |
| 5500 | 12 | 54 | 1 | 90 | 62 | 16 | 8 | 2 | 4 | 54 | III |
| 5500 | 13 | 66 | 1 | 90 | 62 | 17 | 9 | 2 | 4 | 72 | III |

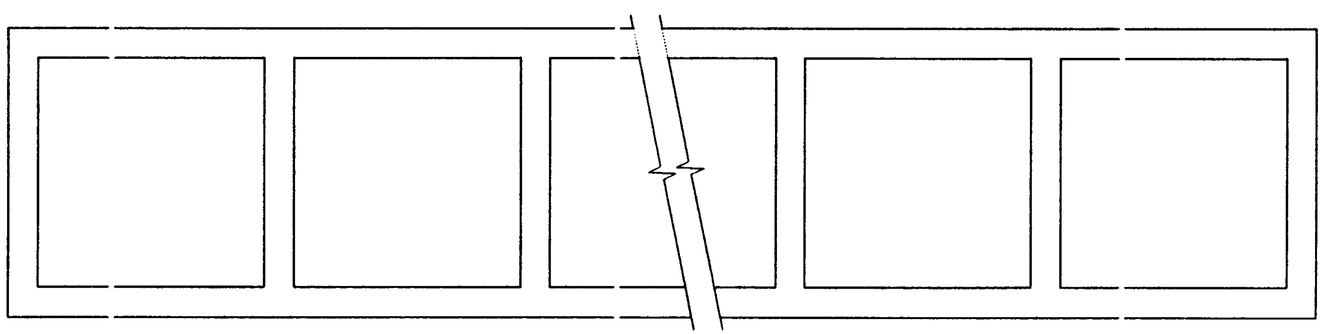
## Table IV-D-3
## Crossings
## Natural Drainage Siphon - Quantities

| Canal No. | Siphon No. | Selected Siphon Diameter (in.) | Number of Siphons | Siphon Length (ft) | Pipe Length (ft) | Trench Depth (ft) | Trench Width (ft) | Flared End Section (ea) | Angled Sections (ea) | Pipe Bedding (cy) | Pipe Class |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5500 | 14 | 54 | 1 | 90 | 62 | 16 | 8 | 2 | 4 | 54 | III |
| 6000 | 1 | 84 | 3 | 200 | 516 | 18 | 30 | 6 | 12 | 687 | III |
| 6000 | 2 | 96 | 1 | 200 | 172 | 19 | 11 | 2 | 4 | 282 | III |
| 6000 | 3 | 96 | 1 | 200 | 172 | 19 | 11 | 2 | 4 | 282 | III |
| 6000 | 4 | 72 | 1 | 200 | 172 | 17 | 9 | 2 | 4 | 181 | III |
| 6000 | 8 | 90 | 1 | 200 | 172 | 19 | 11 | 2 | 4 | 255 | III |
| 6000 | 9 | 66 | 1 | 200 | 172 | 17 | 9 | 2 | 4 | 160 | III |
| 6000 | 10 | 24 | 1 | 200 | 172 | 13 | 5 | 2 | 4 | 46 | III |
| 6000 | 11 | 66 | 1 | 200 | 172 | 17 | 9 | 2 | 4 | 160 | III |
| 6000 | 12 | 78 | 2 | 200 | 344 | 18 | 19 | 4 | 8 | 409 | III |
| 6000 | 13 | 90 | 1 | 200 | 172 | 19 | 11 | 2 | 4 | 255 | III |
| 6200 | 1 | 48 | 1 | 150 | 122 | 15 | 7 | 2 | 4 | 77 | III |
| 6200 | 4 | 96 | 1 | 150 | 122 | 19 | 11 | 2 | 4 | 211 | III |
| 6200 | 5 | 78 | 2 | 150 | 244 | 18 | 19 | 4 | 8 | 307 | III |
| 6200 | 6 | 66 | 1 | 150 | 122 | 17 | 9 | 2 | 4 | 120 | III |
| 6200 | 7 | 48 | 1 | 150 | 122 | 15 | 7 | 2 | 4 | 77 | III |
| 6200 | 8 | 78 | 1 | 150 | 122 | 18 | 10 | 2 | 4 | 153 | III |
| 6200 | 11 | 78 | 1 | 150 | 122 | 18 | 10 | 2 | 4 | 153 | III |
| 6200 | 12 | 90 | 3 | 150 | 366 | 19 | 32 | 6 | 12 | 573 | III |
| 6200 | 13 | 96 | 4 | 150 | 488 | 19 | 44 | 8 | 16 | 846 | III |
| 6200 | 14 | 96 | 5 | 150 | 610 | 19 | 55 | 10 | 20 | 1057 | III |
| 6200 | 15 | 48 | 1 | 150 | 122 | 15 | 7 | 2 | 4 | 77 | III |
| 6200 | 16 | 72 | 1 | 150 | 122 | 17 | 9 | 2 | 4 | 136 | III |
| 6260 | 1 | 54 | 1 | 120 | 92 | 16 | 8 | 2 | 4 | 72 | III |
| 6400 | 2 | 72 | 1 | 130 | 102 | 17 | 9 | 2 | 4 | 118 | III |
| 6600 | 1 | 72 | 2 | 90 | 124 | 17 | 18 | 4 | 8 | 163 | III |
| 6600 | 2 | 60 | 1 | 90 | 62 | 16 | 8 | 2 | 4 | 63 | III |
| 6600 | 3 | 66 | 1 | 90 | 62 | 17 | 9 | 2 | 4 | 72 | III |




**TYPICAL PROFILE**

N.T.S.



NOTE: NUMBER OF BOXES VARIES FROM ONE TO SEVEN

**TYPICAI. CROSS SECTION**

N.T.S.

US Army Corps of Engineers

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

# INVERTED BOX CULVERT

PLATE
IV-D-2

# Grand Prairie Area Demonstration Project

## Structural, Electrical & Mechanical

# APPENDIX IV-E

# UNITED STATES BUREAU OF RECLAMATION

# DESIGN STANDARD No. 3

U.S. Army Corps of Engineers
Memphis District

TERRY COX
CELMV-ET-ES

# DESIGN STANDARDS

# WATER CONVEYANCE SYSTEMS

# NO. 3

## CHAPTER 12

## GENERAL STRUCTURAL CONSIDERATIONS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
TECHNICAL SERVICE CENTER
DENVER, COLORADO

7-2071(6-84)
Bureau of Reclamation

UNITED STATES
DEPARTMENT OF THE INTERIOR
**Bureau of Reclamation**
Technical Service Center
Denver, Colorado
80225-0007

**TRANSMITTAL OF DESIGN STANDARDS** Change No: DS-3(12)-2

Standards Number and Title:

Design Standards No. 3 - WATER CONVEYANCE SYSTEMS

Chapter 12 - General Structural Considerations

Insert Sheets:

Chapter 12 (ALL)

Remove Sheets:

Chapter 12, DRAFT (10/89)

Summary of Changes:

Appropriate offices throughout Reclamation have reviewed and revised these draft Design Standards. This finalized version completely replaces the draft version.

Approved:

R. R. Schaefer
FOR Director
Technical Service Center

8/10/94
Date

(To be filled in by employee who files this change in the appropriate standard.)

The above change has been made in the Design Standards

Signature

Date

DESIGN STANDARDS NO. 3

WATER CONVEYANCE SYSTEMS

# CHAPTER 12 - GENERAL STRUCTURAL CONSIDERATIONS

United States Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

1994

6. Building Code Requirements for Reinforced Concrete (ACI 318-89) and Commentary-ACI 318R-89.

7. Concrete Manual, Bureau of Reclamation, Denver, Colorado, 8th Edition, Reprinted 1988.

8. Design of Small Canal Structures, Bureau of Reclamation, Denver, Colorado, 1974.

9. PCI Design Handbook, Precast and Prestressed Concrete, Precast Concrete Institute, 3rd Edition, 1985.

10. ACI Manual of Concrete Practice 1988, Part 4, Report by ACI Committee 350R-83.

11. "Design Criteria for Concrete Retaining Walls", Report of the task committee on design criteria for retaining walls, Bureau of Reclamation, Denver, Colorado, July 1977.

12. "Application of Strength Design Methods to Sanitary Structures," by Frank Klein, Edward S. Hoffman, and Paul F. Rice, Concrete International, April, 1981.

13. Environmental Engineering Concrete Structures (ACI 350R-89)

14. "Seepage, Drainage, and Flownets", Harry R Cedergren

# Grand Prairie Area Demonstration Project
## Structural, Electrical & Mechanical

# APPENDIX IV-F

# UNITED STATES BUREAU OF RECLAMATION

# STANDARD SPECIFICATIONS

U.S. Army Corps of Engineers
Memphis District

CONTENTS

BEARING PRESSURES



REFERENCES

## INTRODUCTION

### PURPOSE

This chapter contains design information used for many types of water conveyance system structures. The structural designs are generally based on information found in recognized design textbooks. The loadings and standards given in this chapter are adequate for most conditions; however, engineering judgment must be exercised to determine when they do not fit local conditions.

### DATA

It is important that the Design Team identify site-specific design data needs on which the Region and Project can focus collection efforts so costs can be minimized and effectiveness maximized. The data should include drawings and other information necessary for the complete design of the structures. The desirable scale for profile drawings is 1 inch equals 10 feet (1:100 metric) vertical and 1 inch equals 200 feet (1:2 000 metric) horizontal, although a high density of structures may sometimes warrant a horizontal scale of 1 inch equals 100 feet (1:1 000 metric). Profiles and structures should be oriented on drawings so that the stationing increases from left to right or from bottom to top.

## REINFORCED CONCRETE DESIGN CRITERIA

### GENERAL

The current ACI 318 (ACI 318M) American Concrete Institute Building Code Requirements are used as a guide for water conveyance system structures. For additional design criteria pertaining to a particular structure type, refer to the appropriate chapter of these design standards.

In the design of reinforced concrete structures not containing water, members shall be proportioned for adequate strength in accordance with strength design theory, using load factors and strength reduction factors in accordance with ACI 318 (ACI 318M). Load factors shall be applied in a manner which develops the maximum stresses.

## NOTATION

.4 The following notation is used in this section:

| | |
|---|---|
| $U$ | Required strength to resist factored loads or related internal moments and forces based on ACI 318 |
| $U_{wc}$ | Required strength to resist factored loads or related internal moments and forces in water-containing structures |
| $M_d$ | Moment due to dead load |
| $M_l$ | Moment due to live load |
| $M_F$ | Moment due to fluid load |
| $M_E$ | Moment due to earth load |
| $V_{s\,wc}$ | Nominal shear strength provided by shear reinforcement for water-containing structures |
| $V_u$ | Factored shear force at section |
| Ø | Strength reduction factor |
| $V_c$ | Nominal shear strength provided by concrete |
| $f_s$ | Calculated stress in reinforcement at service loads |
| $f_y$ | Specified yield strength of nonprestressed reinforcement |
| z | Quantity limiting distribution of flexural reinforcement |
| $d_c$ | Thickness of concrete cover measured from extreme tension fiber to center of bar or wire located closest thereto |
| A | Effective tension area of concrete surrounding the flexural tension reinforcement and having the same centroid as that reinforcement divided by the number of bars or wires |
| s | Reinforcement bar spacing |

## LOAD FACTORS FOR WATER-CONTAINING STRUCTURES

.5 Structural members of water-containing structures shall also be proportioned on the basis of ultimate strength design by utilizing an additional water-containing coefficient applied to the required strength (U) used for ACI 318 (ACI 318M), which results in increased load factors [10][1]. The required strength for water-containing structures ($U_{wc}$) to resist dead load moments ($M_d$), live load moments ($M_l$), fluid load moments ($M_F$) and earth load moments ($M_E$) shall be:

Flexural reinforcement

$$U_{wc} \geq 1.3\ U$$

Direct tension reinforcement

$$U_{wc} \geq 1.65\ U$$

Shear reinforcement:

$$\varnothing\ V_{s\,wc} \geq 1.3\ (V_u - \varnothing V_c)$$

Concrete shear and compression

$$U_{wc} \geq 1.0\ U$$

No increase is required in load factors [12] for concrete shear or compression strength. Therefore, proportioned member depths or thicknesses are unchanged from those suggested in ACI 318 (ACI 318M). For flexure, the increase in load factors results in a maximum load factor of 2.21 for normal live, fluid, and earth loads, and a minimum load factor of 1.82 for all dead loads. In conjunction with the Ø factors prescribed in ACI 318 (ACI 318M), these load factors generally result in flexural service load stresses in the reinforcement between 24 and 29 kips/in$^2$ (165 and 200 MPa). For pure tension [12], the structural durability coefficient of 1.65 results in a service load stress for liquids of approximately 20 kips/in$^2$ (138 MPa).

## ALLOWABLE STRESSES FOR WATER-CONTAINING STRUCTURES

.6 General. - Most designs for water conveyance system structures are based on 4,000 lb/in$^2$ (28 MPa) strength concrete and reinforcement with a specified minimum yield strength of 60,000 lb/in$^2$ (400 MPa). Most designs for canal, drain, and tunnel linings are based on 3,000 lb/in$^2$

[1] Bracketed numbers identify documents listed in REFERENCES.

(20 MPa) strength concrete. When reinforcement is used, designs for canal, drain, and tunnel linings are based upon the same concrete and reinforcement bar strengths as other water conveyance system structures. Structural members of nonwater-containing structures are to be proportioned by the use of standard ACI 318 (ACI 318M) recommendations.

Beams and one-way slabs. - Many water conveyance structures are water-containing features and are therefore not completely covered by the ACI 318 Building Code provisions for design and construction. To ensure protection of reinforcement against corrosion, many fine hairline cracks are preferable to a few wide cracks. A z factor equal to 115 kips/in$^2$ (20 MN/m) and a crack width equal to 0.010 inch (0.25 mm) are appropriate for normal water quality exposure. Normal water quality exposure [10, 12] can be defined as concrete exposed to water with a pH greater than 5, with a sulfate concentration less than 1,500 ppm, or air-entrained concrete exposed to wet/dry or freeze/thaw cycles. The ACI Building Code requires flexural reinforcement shall be well distributed within maximum flexural tension zones to limit the computed width of cracks. ACI 318 (ACI 318M) establishes the term z, for distribution of flexural reinforcement to control flexural cracking in beams and in one-way slabs:

$$z = f_s \, (d_c A)^{0.333}$$

or for flexural reinforcement of a single size and located in one layer:

$$S = 0.5 \, \frac{\left(\dfrac{z}{f_s}\right)^3}{d_c^2}$$

Allowable service load stresses and bar spacings [10, 12] are established (see fig. 1) to control crack widths to a maximum of 0.010 inch (0.25 mm) for normal water quality exposure. Bar spacings are limited to a maximum of 12 inches (300 mm). Maximum service load stresses are 30 kips/in$^2$ (200 MPa) for grade 60 bars (400 MPa).

The z values were established for cover not to exceed 2 inches (50 mm) and should be based on this value. Additional cover may be regarded as added protection.

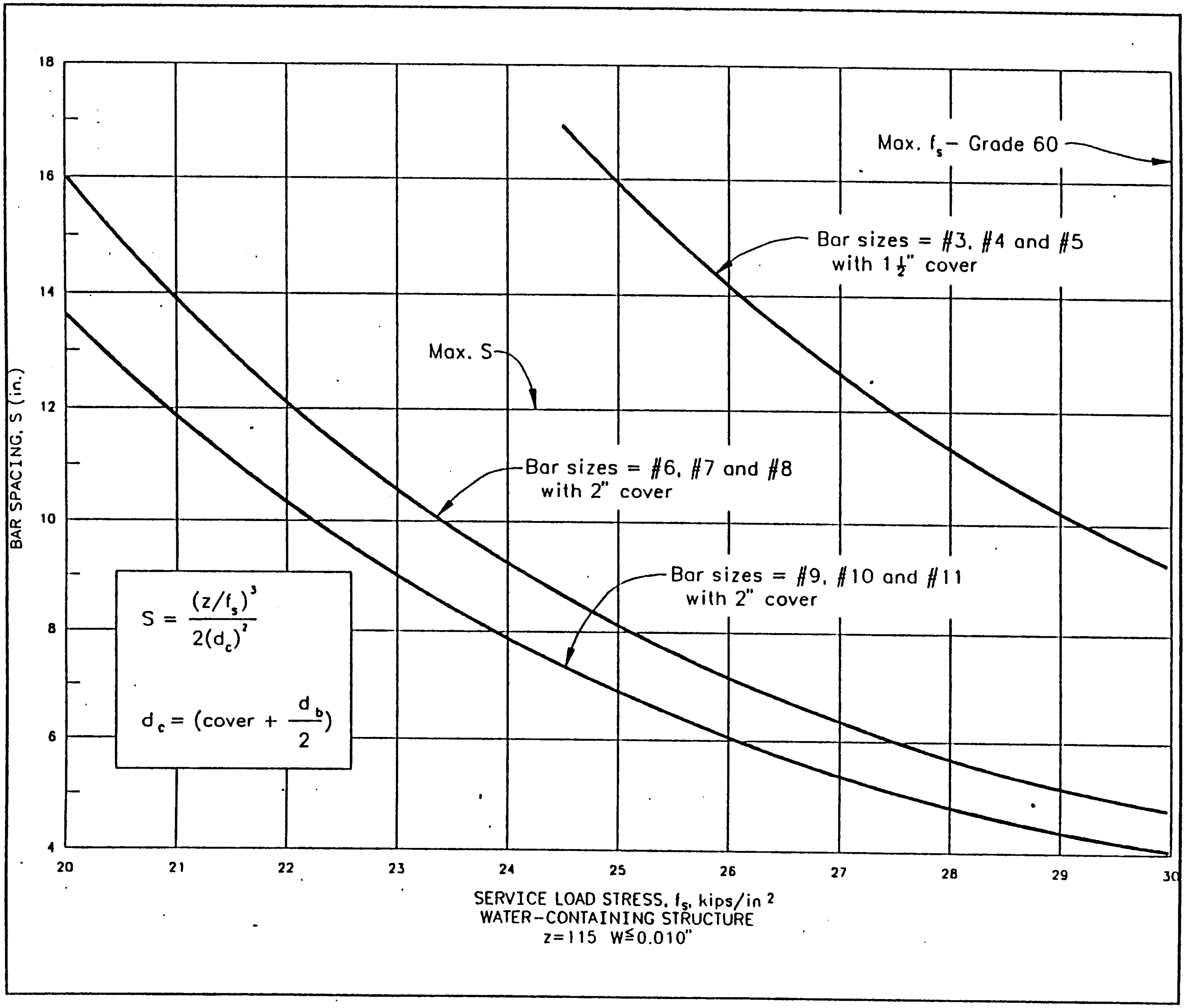

Max. $f_s$ – Grade 60
Bar sizes = #3, #4 and #5 with 1½" cover
Max. S
Bar sizes = #6, #7 and #8 with 2" cover
Bar sizes = #9, #10 and #11 with 2" cover
$S = \frac{(z/f_s)^3}{2(d_c)^2}$
$d_c = (\text{cover} + \frac{d_b}{2})$
BAR SPACING, S (in.)
SERVICE LOAD STRESS, $f_s$, kips/in $^2$
WATER-CONTAINING STRUCTURE
z=115 W≤0.010"
18
16
14
12
10
8
6
4
20
21
22
23
24
25
26
27
28
29
30

Figure 1

Two-way flexural members. - The reinforcement for two-way flexural members (eg., slabs and walls) of water-containing structures shall be proportioned in each direction.

## STRUCTURE AND ANALYSIS METHODS

.7 Practically all reinforced concrete structures constructed by Reclamation are designed as elastic-framed structures with consideration of the continuity or monolithic character of this type of construction. This feature of continuity complicates the problem of determining the amount of bending, shear, and thrust at critical sections of the frame. The structure and member analyses are generally based on information found in recognized analysis text books.

## REINFORCEMENT BAR SPACING AND SELECTION OF BAR SIZE

.8 Spacing of parallel bars should be shown on reinforcement drawings as center to center of adjacent bars. ACI 318 (ACI 318M) defines the minimum spacings for parallel bars not in contact. The maximum reinforcement spacing shall be twice the thickness of the member for stress bars and three times the thickness of the member for temperature bars. In either case, the maximum spacing is 18 inches (450 mm) with a preferred limit of 12 inches (300 mm).

For water-containing structures, the bar spacing and size will be affected by the control of crack width, as discussed in paragraph 12.6, "Allowable Stresses for Water-containing Structures."

To reduce difficulties in shipping, the maximum desirable bar length is 40 feet (12 m). However, #6 (No. 20) bars and larger may have a maximum length of 60 feet (18 m) if necessary. Bars used for designs should be selected so as to limit the number of different sizes when possible. Shipping sizes for bent bars should also be considered.

## DEVELOPMENT OF DEFORMED BARS AND STANDARD HOOKS IN TENSION

.9 Development of reinforcement shall be governed by the current ACI Building Code. Where bars must be anchored (or developed) in tension within a limited distance, a hook can add some capacity [5]. Although a hook is not as good as an equal length of straight bar, a tension hook can be used to advantage where no room exists for the equivalent length of straight bar. The term "standard hook" as used by

Reclamation shall be as stated by ACI 318 (ACI 318M) Building Code.

**REINFORCING BAR SPLICES**

.10 Lengths of splices for reinforcing bars shall be in accordance with the ACI Building Code. The standard drawing 40-D-6263 (4040-D-6263) is available and provides notes and normal requirements for most conditions. To simplify reinforcement patterns and still limit the cracking at splice locations, it is good practice to limit the change in bar diameter at a splice to two bar sizes. When spacing is closer than 6 inches (150 mm), stagger the splices with at least 12 inches (300 mm) between the end of one splice and the beginning of the adjacent splice.

Splice and embedment lengths for epoxy-coated reinforcement bars shall be 50% greater than those required for uncoated bars.

Where splicing of reinforcing steel is to be performed by welding [9], the welding shall conform to AWS D1.4 "AWS Structural Welding Code - Reinforcing Steel." AWS D1.4 indicates that most reinforcing bars can be welded. However, the preheat and other quality control measures that are required for bars with high carbon equivalents are very difficult to achieve. Except for welding shops with proven quality control procedures that meet AWS D1.4, it is recommended that carbon equivalents be limited to
0.45 percent for #7 (No. 25) and larger bars, and
0.55 percent for #6 (No. 20) and smaller bars. Most reinforcing bars which meet ASTM A615 (ASTM A615M including S1), Grade 60 (400 MPa), will not meet the above chemistry specifications. ASTM A615, Grade 40 (300-MPa) bars may or may not meet the above specifications. Bars which meet ASTM A706 (ASTM A706M) are specially formulated to be weldable and should be an option in specifications where welding is allowed. Welding electrodes shall be selected so that the specified yield and tensile strengths are not less than those of the reinforcing steel. Tack welding of grade 60 (400-MPa) bars must be prohibited unless the preceding requirements are met.

**PROTECTIVE COVER**

.11 Concrete protection for reinforcement is given in ACI 318 (ACI 318M) and on drawing 40-D-6263 (4040-D-6263). The dimensions given are clear cover, that is, the outside of the bar deformations to the surface of the concrete. However, on all design or placing drawings, dimensioning of bar location should be given to the centerline of the bars unless otherwise noted.

Protective cover over reinforcement in the top face of concrete exposed to scour shall be increased by 1/2 inch (13 mm) if the water velocity exceeds 10 ft/s (3 m/s) and an additional 1/2 inch (13 mm) for each increment of velocity of 10 ft/s (3 m/s). Surface hardening of the concrete (polymers) or use of silica fume concrete may be evaluated for effectiveness in lieu of the sacrificial concrete cover.

**TEMPERATURE AND SHRINKAGE REINFORCEMENT**

.12 Temperature reinforcement serves as stress distribution reinforcement for spanning the main reinforcement, as well as controlling cracking caused by temperature changes, creep, shrinkage, plastic flow, and other volume changes.

The following criteria shall be used to determine the cross-sectional area of temperature or shrinkage reinforcement required in structures. The percentages indicated are based on the gross cross-sectional area of the concrete face to be reinforced. Where the thickness of the member exceeds 30 inches (750 mm) or for mass concrete, a thickness of 15 inches (375 mm) per face should be used in determining the temperature or shrinkage reinforcement.

Minimum reinforcement. - The minimum reinforcement for structures shall be #4 (No. 10) bars at 12 inches (300 mm) in all exposed faces and where reinforcement is placed in a single layer, and #4 (No. 10) bars at 18 inches (450 mm) in unexposed faces and #4 (No. 10) bars at 12 inches (300 mm) in exposed faces with two-layer reinforcement.

Single-layer reinforcement. -

| Structure type | Water-containing structures (percent) | Other structures (percent) |
|---|---|---|
| 1. Reinforced concrete linings 4 inches (100 mm) and less in thickness with discontinuous wire-fabric reinforcement and weakened planes at 12- to 15-foot (3.5- to 4.5-m) centers. | 0.10 | --- |
| 2. Slabs and linings not exposed to freezing temperatures or direct sun with joints not exceeding 30 feet (9 m). | 0.25 | 0.18 |
| 3. Slabs and linings exposed to freezing temperatures or direct sun with joints not exceeding 30 feet (9 m). | 0.30 | 0.20 |
| 4. Slabs and linings exceeding 30 feet (9 m) between joints: | | |
| Category 2 above | 0.35 | 0.20 |
| Category 3 above | 0.40 | 0.25 |

Double-layer reinforcement. -

In members with double-layer reinforcement, the total percentage of horizontal reinforcement is to be equal to the sum of those required for both faces as determined below.

| Structure type | Water-containing structures (percent) | Other structures (percent) |
|---|---|---|
| 1. Face adjacent to earth with joints not exceeding 30 feet (9 m). | 0.10 | 0.06 |
| 2. Face not adjacent to earth nor exposed to freezing temperatures or direct sun and with joints not exceeding 30 feet (9 m). | 0.15 | 0.10 |
| 3. Face not adjacent to earth but exposed to freezing temperatures or direct sun and with joints not exceeding 30 feet (9 m). | 0.20 | 0.13 |
| 4. If member exceeds 30 feet (9 m) in any direction parallel to reinforcement, add to the reinforcement requirement in that direction because of the increased length. | 0.05 | 0.05 |

If a slab is fixed along any line, double the dimension from line of fixity to the free end to determine whether reinforcement is within less than 30 feet or more than 30 feet (9 m); percentages shown under 1, 2, 3, and 4 above.

**MINIMUM SLAB AND WALL THICKNESS**

.13 The minimum dimensions for slabs and walls are restricted by the following requirements:

Walls having two-layer reinforcement shall be 8 inches (200 mm) thick minimum. Two-layer reinforcement is required in walls 8 inches (200 mm) thick or greater.

Cantilever walls shall have a minimum thickness at the base equal to 1 in/ft (25 mm/300 mm) of height up to 8 feet (2.5 m); above 8 feet (2.5 m), the minimum thickness at the base shall be 8 inches (200 mm) plus

3/4 inch (20 mm) for each foot (300 mm) in height above 8 feet (2.5 m).

When the control of deflection in walls or slabs is required, the thickness shall be proportioned so the area of reinforcement required is less than 35 percent of the balanced area of reinforcement design.

Transition buttresses normally have the following thicknesses and reinforcement:

| Height of buttress, ft (m) | Thickness of buttress, in (mm) | No. of layers of bars | Size of bars | Spacing of bars, in (mm) | Location of bars |
|---|---|---|---|---|---|
| 0-10 (0-3) | 8 (200) | 1 | #4 (No. 20) | 12 (300) | Center |
| 10-15 (3-4.5) | 10 (250) | 1 | #5 (No. 25) | 12 (300) | Center |
| 15-20 (4.5-6) | 12 (300) | 1 | #5 (No. 25) | 12 (300) | Center |

The wall thickness of box-type structures generally shall be designed to resist total shear forces without the use of shear reinforcement.

The floor slab of monolithic concrete structures is generally at least 1 inch (25 mm) thicker than otherwise required to allow for the unformed earth surface irregularities and added cover requirements for concrete placed against earth or rock. Shear forces may require even greater floor slab thickness.

### WELDED WIRE FABRIC FOR REINFORCEMENT

.14 Welded wire fabric may be substituted for deformed reinforcing bars where it is deemed beneficial. Smooth or deformed welded wire fabric may be used in accordance with the applicable paragraphs of ACI 318 (ACI 318M) Building Code Requirements for Reinforced Concrete.

### CUTOFF WALLS

.15 Cutoffs are provided to reduce percolation around canal and drain structures, to prevent movement of structures, and to make transitions more rigid. Cutoffs are provided on cross-drainage culverts to prevent undercutting of the structure foundation by erosion. Cutoffs are required at the ends of structure transitions in concrete-lined canals as well as in other lined or earth canals. In general, cutoff walls should have the following minimum dimensions:

| d (water depth) (ft) | Cutoff depth (ft) | Cutoff thickness (in) |
|---|---|---|
| <3.0 (<1.0 m) | 2-0 min. (0.5 m) | 6 (150 mm) |
| 3-6 (1-2 m) | 2-6 (0.75 m) | 8 (200 mm) |
| >6 (>2 m) | 3-0 (1.0 m) | 8 (200 mm) |

In soils that are unusually susceptible to piping, the cutoff should be extended horizontally or vertically, or both, to provide adequate protection against percolation. Care should be taken to make the cutoffs wide enough and deep enough to be effective under unknown soil conditions where investigations are inconclusive prior to design. The vertical reinforcement in the cutoff is usually the same as the longitudinal reinforcement in the transition floor. If only one layer of reinforcement is used in a cutoff, the vertical reinforcement should be placed in the center of the cutoff wall.

For canals in soils that are unusually susceptible to piping or where the differential pressure is large, a reinforced-concrete lining with waterstop joints may be considered as an apron against percolation.

Where cutoff walls are used to prevent movement of structures, they must be designed to resist reactive passive earth pressures.

## JOINTS IN STRUCTURES

.16 Construction, contraction, and expansion joints are often used in concrete and canal structures.

Construction joints. - Construction joints are joints which are purposely placed in structures to facilitate construction or which occur in structures as a result of inadvertent delays in concrete placing operations. Construction joints are located to facilitate the contractor's operations, to reduce initial shrinkage stresses and cracks, to allow time for the installation of embedded metalwork, or to allow for the subsequent placing of other concrete, backfill concrete, or second-stage concrete. They are junctions produced by placing fresh concrete against surfaces of hardened concrete. Construction joints are generally placed in the vertical or horizontal directions. In either case, a bond is required at construction joints regardless of whether reinforcement is continuous across the joint.

Construction joints not required for structural reasons are labeled "Optional Construction Joints" and may be omitted if the construction contractor so elects. Construction joints not labeled "Optional" on the construction drawings must be provided for by the contractor in his bidding and in actual construction. Construction joints are required where large masses of concrete connect with smaller masses and where high vertical placements join extensive horizontal placements. Construction joints provide for most of the contraction and vertical settlement shrinkage which occurs in concrete and furnishes a straight "crack" instead of the inevitable ragged crack. In the lower portion of the structure, such uncontrolled cracks would not have the seals provided to prevent leakage of water through the joint. A waterstop may be used in construction joints where a watertight joint is essential.

Contraction joints. - Contraction joints are joints placed in structures or slabs to provide for volumetric shrinkage of a monolithic unit or movement between monolithic units. These joints differ from construction joints in that means are taken to prevent bond between the concrete surfaces forming the joint. The joints are made by forming the concrete on one side of the joint and allowing it to set before concrete is placed on the other side of the joint. The surface of the concrete first placed at a contraction joint shall be coated with a wax-base sealing compound before the concrete on the other side of the joint is placed. If steel bars or dowels extend across the joint, one end of the bar should be coated or wrapped with paper to prevent bonding to the concrete. A waterstop may be used in contraction joints where a watertight joint is essential.

Expansion joints. - Expansion joints are used to eliminate or greatly reduce compressive stresses in concrete that would result from thermal expansion of the concrete. An elastic filler is provided at the joint to permit expansion. When it is necessary to prevent water from passing through a joint, a rubber waterstop with center bulb should be placed across the joint. The use of rubber waterstops provides for possible movement in more than one direction, such as expansion and contraction horizontally, unequal settlement vertically, and possibly a change in relative position of one unit or part of a structure in horizontal relationship to an adjacent unit.

Finned plastic waterstops may be used in lieu of rubber waterstops for structures with heads of 150 feet (45 m) or less.

For additional details, see figure 2.

**FILLETS**

.17 Fillets may be used to provide increased strength or relieve stress concentrations at points of maximum stress. The member span length may be taken to extend 1/3 of the fillet size away from the wall face.

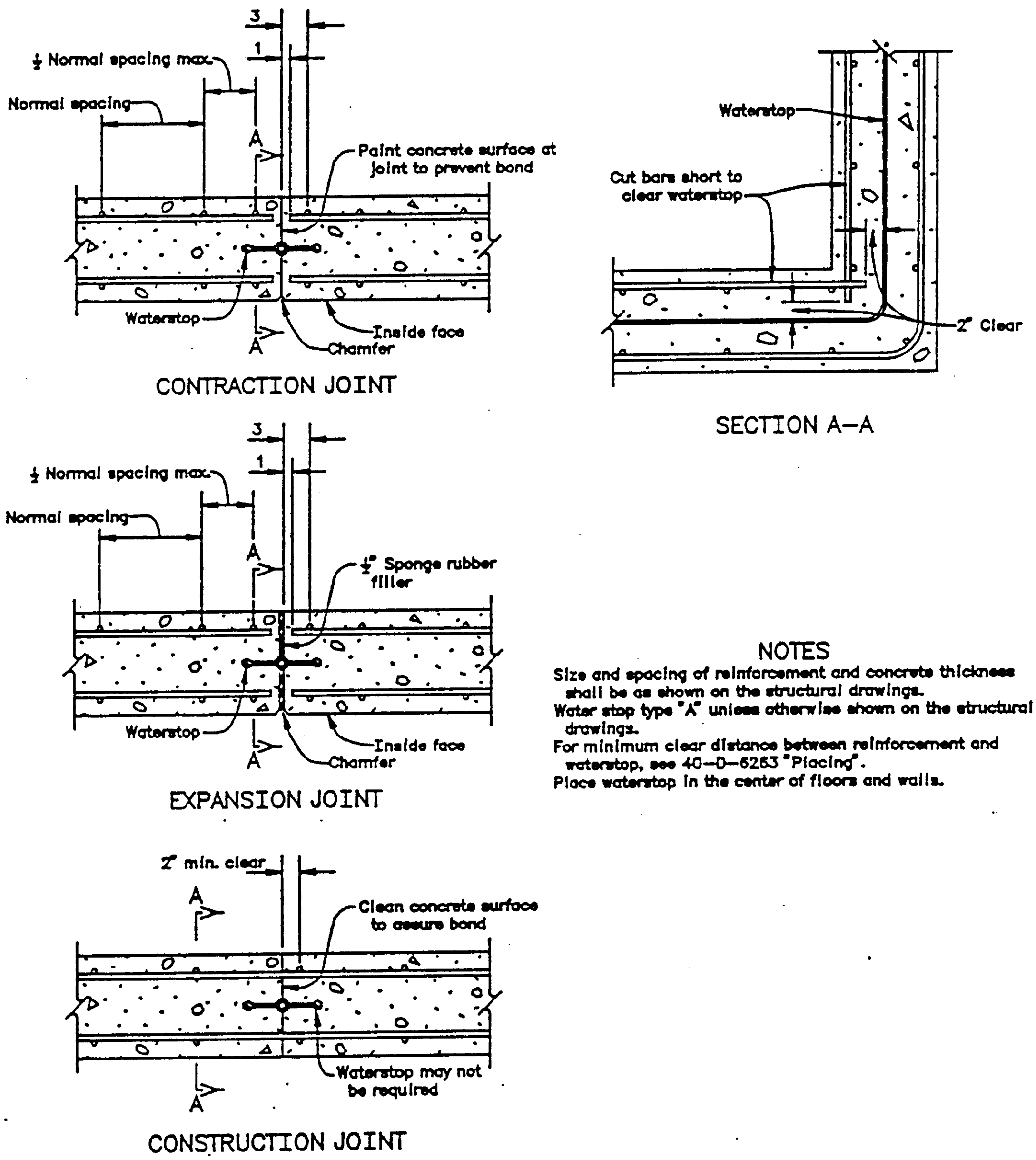
Fillets cause difficulties during constuction and should be used only when design stresses require.

## LOADINGS

**GENERAL**

.18 Owing to the nature of some water conveyance structures, unusual loading conditions often exist. The structures are subjected to changing effects such as foundation reactions, earthquakes, temperature stresses, exposure conditions, frost heaving, and varying earth and hydrostatic loadings. All structures shall be designed to withstand any probable dead and live loads. Where appropriate, earthquake loadings are applied to structures in accordance with the method outlined in "Design Criteria for Concrete Retaining Walls" [11] or other suitable codes. If the potential for soil liquefaction exists, foundation treatment (e.g. dynamic compaction, removal and replacement) to proclude or mitigate liquefaction should be investigated.

The loadings used should be shown on the design drawings.




NOTES

Size and spacing of reinforcement and concrete thickness shall be as shown on the structural drawings.
Water stop type "A" unless otherwise shown on the structural drawings.
For minimum clear distance between reinforcement and waterstop, see 40–D–6263 "Placing".
Place waterstop in the center of floors and walls.

Figure 2

## NOTATION

.19 The following notation is used in these paragraphs on loadings:

- $EFP_a$ Active soil equivalent-fluid-pressure, $lb/ft^2/ft$ $(N/m^2/m)$
- $EFP_p$ Ultimate passive equivalent fluid pressure, $lb/ft^2/ft$ $(N/m^2/m)$
- $EFP_o$ At-rest equivalent soil pressure, $lb/ft^2/ft$ $(N/m^2/m)$
- $\gamma$ Density of the soil, $lb/ft^3$ $(N/m^3)$
- H Height of horizontal backfill, ft (m)
- Ø Internal friction angle of the soil

## DEAD LOADS

.20 The dead load due to permanent features or special construction is determined by the engineer responsible for the design or procurement of the particular feature in question [2]. Dead load consists of the actual weight of soil cover and of the structure itself, including the wall, floors, roofs, and all other permanent features.

The commonly used densities for computing dead load values are as follows:

| Material | Density, $lb/ft^3$ |
|---|---|
| Water | 62.5 (9.8 $kN/m^3$) |
| Moist uncompacted earth | 100 (15.5 $kN/m^3$) |
| Compacted earth | 120 (19.0 $kN/m^3$) |
| Saturated earth | 135 (21.0 $kN/m^3$) |

Some soils may require variations from the above weights.

## LIVE LOADS

.21 Live loads for each structure are determined by the engineer in responsible charge of the design of the particular feature in question after making a study of the nature of the load distribution, possible concentrated loads, vibration and impact, and related features [2]. Live loads consist of lateral earth loads [6], static or dynamic water loads, moving objects, equipment, gate and hoist equipment and impact loads, snow and wind loadings, construction loads, earthquake and blasting loads when applicable, and loads due to maintenance operations.

Where construction or operating equipment may come close to a structure, a surcharge equal to 2 feet (0.6 m) of earth is normally added.

**LATERAL EARTH LOADS**

.22 A large number of formulas have been developed for the determination of lateral earth pressures, but the solution requires considerable knowledge of assumptions in regard to the characteristics of the earth material exerting the pressures.

The commonly used horizontal active earth equivalent fluid pressures, in pounds per square foot per foot of depth, are as follows:

| Material | $lb/ft^2/ft$ |
|---|---|
| Moist uncompacted earth | 30 ($4.7\ kN/m^2/m$) |
| Compacted earth | 35 ($5.5\ kN/m^2/m$) |
| Saturated earth | 87.5 ($13.7\ kN/m^2/m$) |

Some soils may require variations from the above pressures.

For all practical purposes and for most material involved, sufficiently accurate results may be determined from the Rankine theory of cohesionless soil against smooth vertical walls [11].

Walls sloped flatter than 1-1/2:1 are usually designed to be supported by the foundation upon which they are placed. See figure 3 for resulting pressures on walls sloped more steeply than 1-1/2:1.

Buttress walls are often used for large transitions, and the maximum loads from both sides of the wall must be considered.

Lateral earth loads may be defined as active, passive, and at-rest. A discussion [11, 3] of each type of lateral earth load follows.

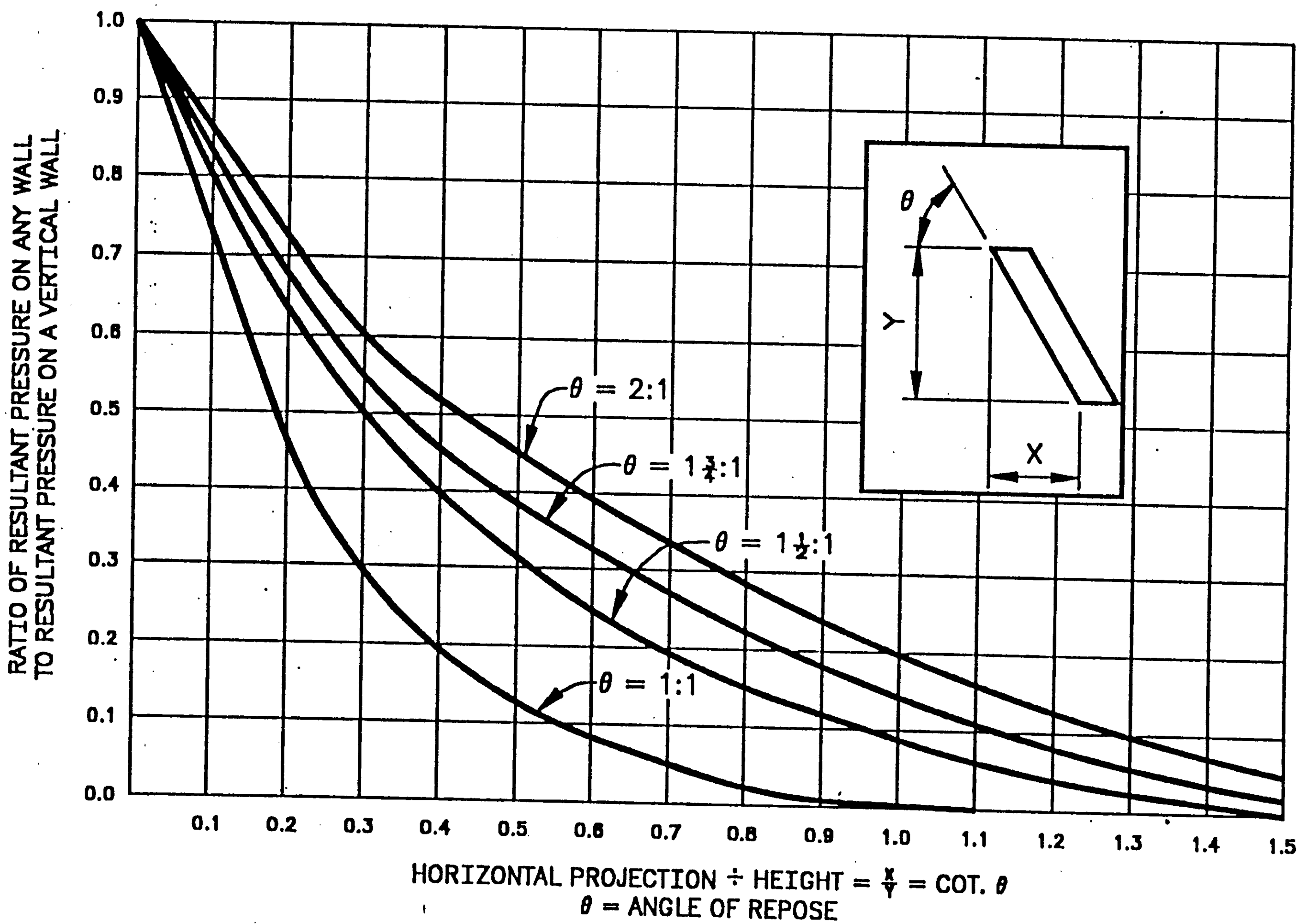

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
RATIO OF RESULTANT PRESSURE ON ANY WALL
TO RESULTANT PRESSURE ON A VERTICAL WALL
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
HORIZONTAL PROJECTION ÷ HEIGHT = X/Y = COT. θ
θ = ANGLE OF REPOSE
θ = 2:1
θ = 1 3/4:1
θ = 1 1/2:1
θ = 1:1
θ
Y
X

Figure 3

Active pressure. - If a structure yields away from the initial position of the soil so that the soil strains laterally, then the lateral pressure of the soil against the structure gradually decreases and approaches a lower limiting value known as active pressure.

$$EFP_a = \gamma \, H \tan^2 (45-\emptyset/2)$$

Where the backfill slopes up from the structure, an additional horizontal force is exerted on the wall. Figures 3, 4, 5, and 6 may be used for computing the horizontal earth pressure and moment for cantilever walls.

Passive pressure. - If a structure is forced into the soil, thus compressing the soil in a lateral direction, the resistance of the soil gradually increases until it assumes an upper limiting value known as passive pressure.

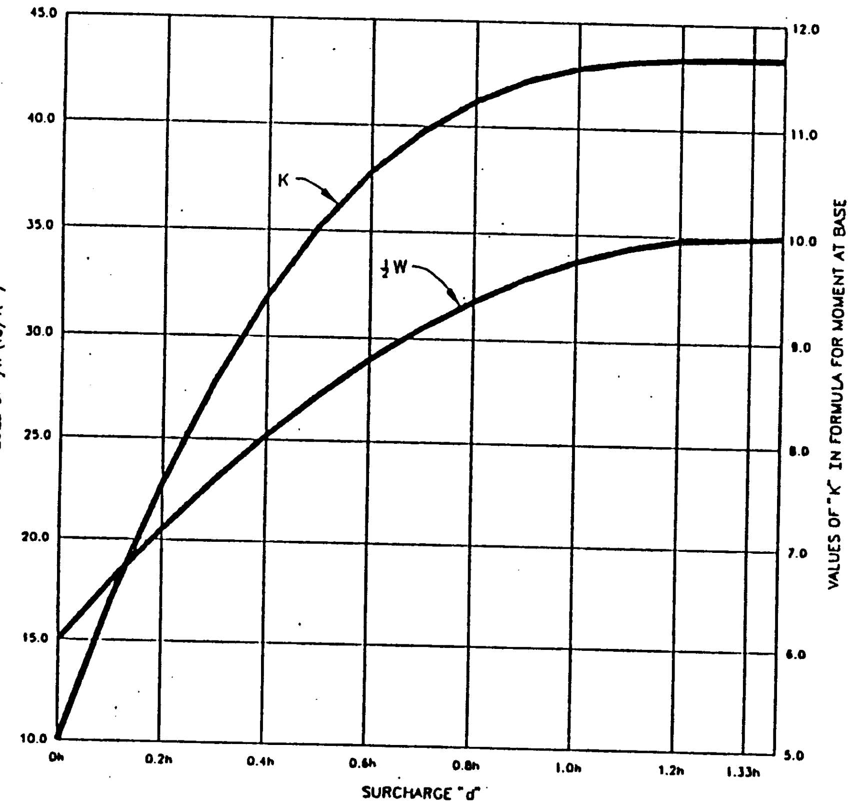
$$EFP_p = \gamma \, H \tan^2 (45 + \emptyset/2)$$

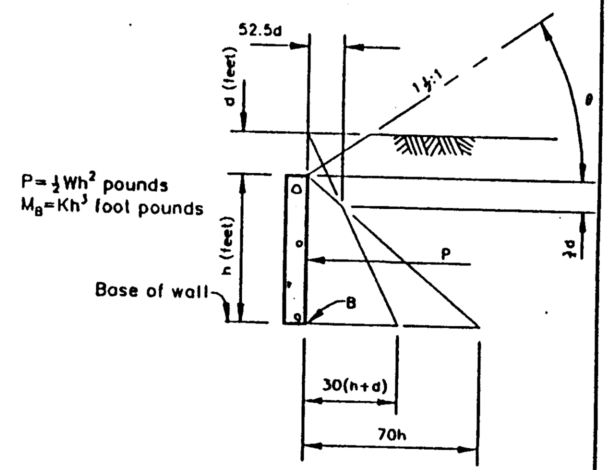
It is recommended to use an allowable passive soil pressure equal to the $EFP_p$ divided by the appropriate safety factor. The safety factor required for design [3, 4, 11] depends on how accurately the soil conditions and the structural loads are known and what hazards are involved in a stability failure. Any future changes in the site, such as a rising water table or excavation adjacent to a footing/blocking that will reduce the surcharge, must be taken into account by the ultimate stability equation or else included in the safety factor. For temporary construction work where a failure would be inconvenient but not disastrous, a safety factor of 1.5 is required. For most cases of structural design where there is reasonably accurate data on the soil and loadings, a safety factor of 2.5 is employed with dead load plus full live load. If a large part of the live load is not likely to develop, a minimum safety factor of 2 is permissible. When the conditions are questionable, a safety factor of 4 is sometimes warranted.

The maximum allowable $EFP_p$ should not exceed the allowable soil bearing pressure stated in paragraph 12.31.

When soil becomes saturated, the effective soil weight is reduced to the density of the saturated soil minus the density of water (i.e., 135 lb/ft$^3$ - 62.5 lb/ft$^3$ = 72.5 lb/ft$^3$). The passive lateral force capacity resulting

Figure 4



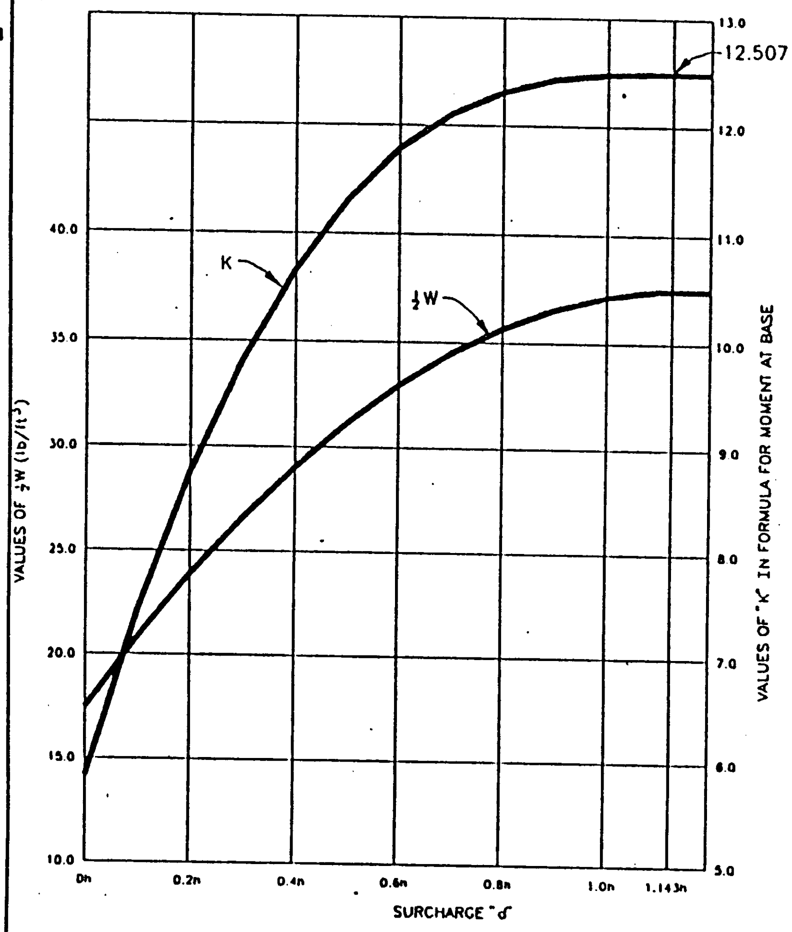

Note; Pressures in lb/ft² are based on the following equivalent unit weights of fluid;

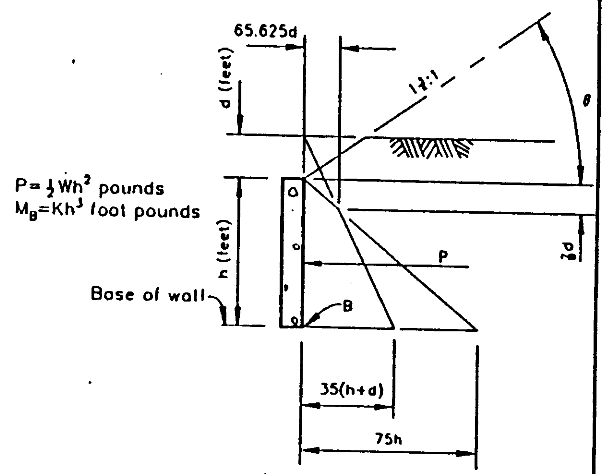
W=30 lb/ft³ for no surcharge
W=70 lb/ft³ for infinite surcharge having slope of 1½:1.

EARTH PRESSURE AND MOMENT CURVES
VERTICAL WALL WITH SURCHARGE

ANGLE OF REPOSE = ANGLE OF SURCHARGE = 1½ TO 1

Figure 5

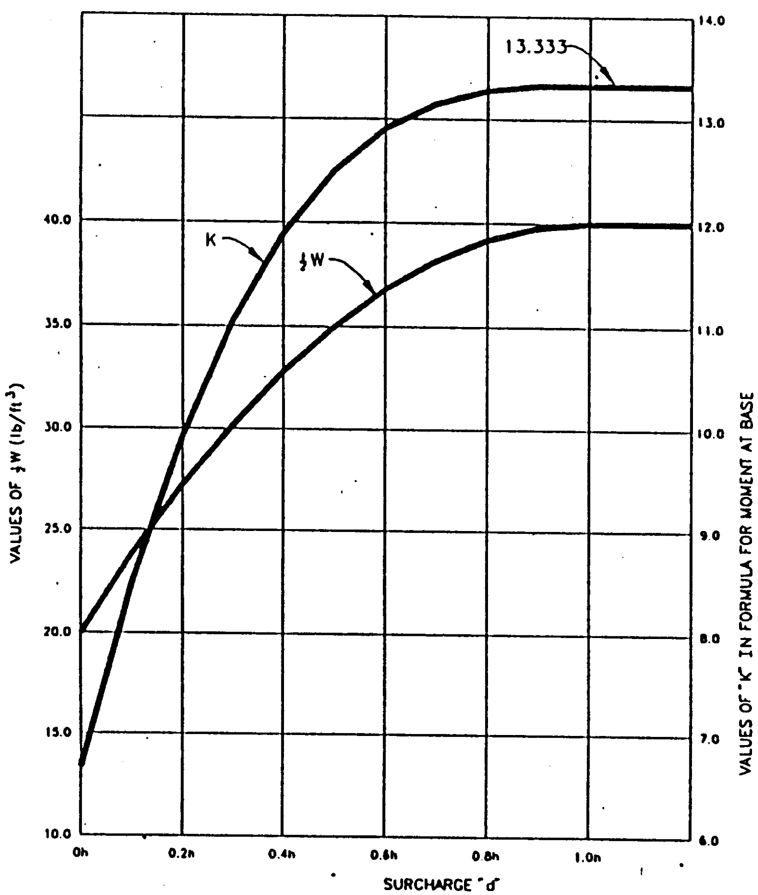


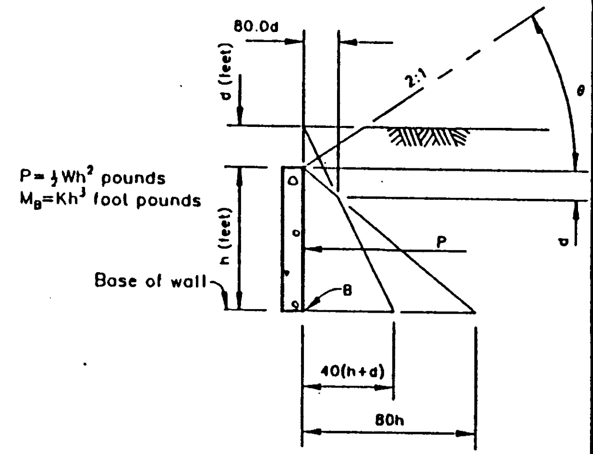




Note; Pressures in $lb/ft^2$ are based on the following equivalent unit weights of fluid;

$W=35\ lb/ft^3$ for no surcharge
$W=75\ lb/ft^3$ for infinite surcharge having slope of 1½:1.

EARTH PRESSURE AND MOMENT CURVES
VERTICAL WALL WITH SURCHARGE
ANGLE OF REPOSE = ANGLE OF SURCHARGE = 1½ TO 1




Note; Pressures in lb/ft² are based on the following equivalent unit weights of fluid;

W=40 lb/ft³ for no surcharge
W=80 lb/ft³ for infinite surcharge having slope of 2:1.

EARTH PRESSURE AND MOMENT CURVES
VERTICAL WALL WITH SURCHARGE
ANGLE OF REPOSE = ANGLE OF SURCHARGE = 2 TO 1

from saturated soil is the soil force based on the buoyant weight.

At-rest pressure. - If the deformation modulus of the structure foundation is high and the structure itself is rigid so that there is little or no lateral strain of the fill, then the structure is resisting lateral fill pressure known as at-rest pressure. The value for at-rest pressure may be estimated by Jaky's equation:

$$EFP_o = \gamma \ H \ (1-\sin \emptyset)$$

When soil becomes saturated, the effective soil weight is reduced to the density of the saturated soil minus the density of water (i.e., 135 $lb/ft^3$ - 62.5 $lb/ft^3$ = 72.5 $lb/ft^3$). The lateral force resulting from saturated soil is the soil force based on the buoyant weight plus the hydrostatic water force.

### HIGHWAY AND RAILROAD LOADS

.23 Some State highway commissions and railroad companies have special requirements and standards which must be followed for structures on their right-of-way. Refer to current American Association of State Highway and Transportation Officials (AASHTO) specifications for design information.

## STABILITY OF STRUCTURES

### GENERAL

.24 The stability analysis should demonstrate by means of adequate factors of safety the ability of the structure to resist the forces tending to cause overturning, sliding, and flotation without exceeding allowable foundation bearing values. The analysis should show clearly the individual external loadings for the various cases during and after construction, the assumed area of base, the magnitude and distribution of the normal and sliding forces at the foundation level, the location of the principal contraction and expansion joints, the uplift assumptions, and any other factors entering into the calculations. Combinations of maximum or minimum loads which have been positioned, included, or excluded in such a way as to produce maximum effects on the stability should be indicated.

## NOTATION

.25 The following notation is used:

| | |
|---|---|
| A | Area of base or horizontal section considered (in compression) |
| c | Cohesion or unit shearing resistance, applied only to area in compression |
| f | Coefficient of friction between concrete and foundation material or between concrete and concrete |
| Q | Shear-friction factor of safety |
| U | Uplift, assumed acting over 100 percent of area |
| $\Sigma H$ | Sum of horizontal forces |
| $\Sigma M_o$ | Overturning moment about toe |
| $\Sigma M_r$ | Resisting moment about toe |
| $\Sigma W$ | Sum of vertical forces, except uplift |
| $F_s$ | Factor of safety |
| T | Thrust force |
| $F_p$ | Passive soil force required |
| $F_a$ | Active soil force |
| $F_{pu}$ | Factored passive resistance load on concrete structure |

## FOUNDATIONS

.26 Allowable foundation design values based upon an exploration program and field and laboratory tests should preferably be used. However, if these are not available, but the type of material is known, the criteria and values given in paragraph 12.31 may be used.

The importance of foundation pressure distribution investigations increases proportionately with the yielding characteristics of foundation materials. Relocation of the structure at a site with better quality foundation material is a first choice. Preconsolidation of the foundation material may also be considered. When poor materials, such as loose sand, soft clay, or soft silt layers and pockets are encountered, but overexcavating a reasonable amount can help to obtain a more satisfactory foundation material, the poor material should be removed and replaced with compacted backfill. Vertical and batter piles may be necessary in some cases.

**OVERTURNING**

.27 The eccentricity of the resultant of the applied loads on the plane of contact of the concrete on the foundation material should be fully investigated. This eccentricity should fall within the middle 1/3 of the base. The maximum bearing pressure should not exceed the allowable bearing value.

**SLIDING**

.28 Frictional resistance to sliding plus shear resistance to sliding is expressed as $(\Sigma W - U) f + cA$. The coefficient of friction and the cohesion or unit shearing strength should be established, if possible, by laboratory testing of foundation materials from the site. The value of shearing strength will depend upon the shearing strengths of the rock and the concrete. If the shearing strength of the rock is the lower value of the two, it should be used in calculating the shear-friction factor, or vice versa. For preliminary design, the following approximate values may be assumed or values may be obtained from existing laboratory reports on similar materials.

| Material | f | c (lb/in²) |
|---|---|---|
| Concrete - 3,000 lb/in² (20 MPa) at 28 days | 0.80 | 440* (3000 kPa) |
| Rock - sound, massive | 0.80 | 400 (2800 kPa) |
| Rock - fractured, jointed | 0.60 | 100 (700 kPa) |
| Gravel | 0.50 | 0 |
| Sand | 0.40 | 0 |
| Clay, firm | 0.30 | 10 (70 kPa) |
| Clay, soft | 0.20 | 2 (14 kPa) |

* Ultimate shearing strength of $8\sqrt{f'_c}$ or 440 lb/in² for 3,000-pound concrete at 28 days.

For structures founded on clay or other low friction material, it may be necessary to add concrete keys, monolithic with the foundation mat, to provide sufficient resistance to sliding by lowering or tilting the level of the sliding plane. In some cases, such as those involving earthquake forces, piles may be required. For structures with stepped concrete bottoms, not more than 60 percent of the area of the flat part of the upper step shall be considered in computing cA because of the usual breakage of the foundation steps.

Structures which are subjected to hydraulic thrust forces, such as pipeline valve vaults or canal check structures during the dewatering of a downstream pool, should first be checked for frictional resistance to sliding using the following equation:

$$F_s = \frac{(\Sigma W - U)\ f}{(T + F_a)}$$

If the safety factor is lower than desired (usually 1.5), then the potential for sliding is indicated. If the structure should not be allowed to move, weight should be added to the structure. When the structure is allowed to move into the soil, lateral soil forces come into play. The safety factor should then be calculated as follows:

$$F_s = \frac{(\Sigma W - U)\ f + F_p}{(T + F_a)}$$

If the amount of resisting soil force needed exceeds the at-rest soil force then the structure may be forced into the soil and produce passive soil pressures. If the potential for sliding exists, the portion of the concrete structure subjected to the passive earth pressure is to be designed for this force. This can be done by applying a live load factor to $F_a$ and T and factoring $(\Sigma W + U)f$ down by 0.9 as shown below:

$$F_{pu} = 1.7\ (F_a + T) - 0.9\ (\Sigma W - U)\ f$$

## FLOTATION

.29 All structures should be designed for full-uplift pressure if water under pressure has access to the foundation of the structure. The uplift pressure should be assumed to have a straight-line variation between points of known pressure. Earthquake shocks are assumed to have no effect on uplift pressure.

In many cases, the pressure assumptions, both lateral and uplift, can be greatly reduced with the use of properly designed drains [14].

## FACTORS OF SAFETY

.30 All factors of safety are expressed as the ratio of the resisting forces to the forces tending to cause movement.

Factor of safety against:

$$Overturning = \frac{\Sigma M_r}{\Sigma M_o}$$

$$Sliding = \frac{(\Sigma W - U)\ f + cA}{\Sigma H}$$

$$Flotation = \frac{\Sigma W}{U}$$

The requirements for stability are established by the minimum factors of safety shown in table 1.

Table 1. - Minimum factors of safety

| Minimum factor of safety | During construction loading | | Structure completed and equipment operating loading | |
|---|---|---|---|---|
| | Normal | Extreme | Normal | Extreme |
| Overturning | 3.0 | 1.5 | 3.0 | 1.5 |
| Sliding | 1.5 | 1.1 | 2.0 | 1.5 |
| Flotation | 1.1 | 1.1 | 1.2 | 1.1 |

Maximum ratio of the allowable bearing value to the actual foundation bearing strength found by test should equal no

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Table 2

| Material | Allowable bearing value ($T/ft^2$) |
|---|---|
| Massive bedrock without lamination, such as granite rocks, gneiss, trap rock, felsite, and thoroughly cemented conglomerates, all in sound condition (sound condition allows some cracks) | 100 (9550 $kN/m^2$) |
| Laminated rocks, such as slate and schists, in sound condition (some cracks allowed) | 35 (3350 $kN/m^2$) |
| Shale in sound condition (some cracks allowed) | 10 (955 $kN/m^2$) |
| Residual deposits of shattered or broken bedrock of any kind except shale | 10 (955 $kN/m^2$) |
| Hardpan | 10 (955 $kN/m^2$) |
| Gravel, sand-gravel mixtures, compact | 5 (475 $kN/m^2$) |
| Gravel, sand-gravel mixtures, loose; sand, coarse, compact | 4 (380 $kN/m^2$) |
| Sand, coarse, loose; sand, fine, compact | 3 (285 $kN/m^2$) |
| Sand, fine, loose | 1 (95 $kN/m^2$) |
| Hard clay | 6 (570 $kN/m^2$) |
| Medium clay | 4 (380 $kN/m^2$) |
| Soft clay | 1 (95 $kN/m^2$) |

Underlaying stratum of smaller bearing value. - Where the bearing materials directly under a foundation overlie a stratum having smaller allowable bearing values, these smaller values should not be exceeded at the level of such a stratum. Computations of the vertical pressure in the bearing materials at any depth below a foundation should be made on the assumption that the load is spread uniformly at an angle of 60° with the horizontal, but the area considered as supporting the load should not extend beyond the intersection of 60° planes of adjacent foundations.

Effect of water in foundation. - Whenever, in an excavation, an inward or upward flow of water develops in an otherwise satisfactory bearing material, such methods should be adopted as necessary to stop or control the flow in order to prevent disturbance of the bearing material. If such flow of water seriously impairs the structure of the bearing material, the allowable bearing value should be reduced to that of the material in loose condition, except in the case of quicksand where no load could be supported.

**LOADINGS**

.32 The loads to be used in computing the maximum pressure upon bearing materials under footings should include live and dead loads of the structure including the weight of footings but excluding loads from any overlying soil.

**DIFFERENTIAL SETTLEMENT**

.33 Where portions of the footing of an entire structure rest directly upon or are underlain by medium or soft clay or rock flour, and other portions rest upon different materials, or where the layers of such softer material vary greatly in thickness, the magnitude and distribution of the probable settlement should be investigated, and if necessary, the allowable loads should be reduced or special provisions should be made in the design of the structure to prevent dangerous differential settlements.

REFERENCES

1. Design Standards No. 3, "Canals and Related Structures," Bureau of Reclamation, Denver, Colorado, December 8, 1967.

2. Design Standards No. 9, "Buildings," Bureau of Reclamation, Denver, Colorado, June 26, 1972.

3. Sowers and Sowers, Introductory Soil Mechanics and Foundations, 3rd Edition, 1970.

4. Terzaghi and Peck, Soil Mechanics in Engineering Practice, 1967.

5. Ferguson, Reinforced Concrete Fundamentals, 4th Edition, 1979.

M-15
(M0150000.091)

# Standard Specifications

for

Rubber Gaskets for Joining Pipe

October 25, 1991

United States
Department of the Interior
Bureau of Reclamation
Assistant Commissioner - Engineering and Research
Denver Office
Denver Federal Center, Building 67
Denver, Colorado 80225-0007

CONTENTS

STANDARD SPECIFICATIONS FOR

RUBBER GASKETS FOR JOINING PIPE

1. General. - Rubber gaskets for joining pipe shall be manufactured and tested in accordance with these specifications and contract requirements. Rubber gaskets, as used herein, shall include both ordinary (non-petroleum-resistant) and petroleum-resistant gaskets. These specifications are not intended for gaskets used with cast iron (ductile iron) pipe.

Contract, as used herein, shall mean the contract which, by reference, these specifications are included in and made a part. Contracting Officer, as used herein, shall mean the person executing the contract on behalf of the Government, and shall include duly authorized representatives. Contractor, as used herein, shall mean the party entering into the contract with the Government, and shall include subcontractors, suppliers, manufacturers, and agents at all tiers.

2. Submittals. - Submittals shall be in accordance with these specifications and the paragraph in section 1.1 of the contract entitled "Submittal Requirements." The Contractor shall be responsible for the accuracy of all submittals.

At least 40 days prior to procurement of the pipe, the Contractor shall submit, for approval, rubber-gasket data for all gaskets proposed for use, including design cross-sectional dimensions, design stretch, and certified test results demonstrating conformance with the physical properties requirements of these specifications.

3. Materials. - Rubber gaskets shall be fabricated from a high-grade rubber compound containing no scrap, reclaim, or rubber substitute. The principal polymer of the compound may be either natural rubber, synthetic rubber, or a blend of both for ordinary gaskets; and Chloroprene or Nitrile Butadiene for petroleum-resistant gaskets. Fabricated gaskets shall meet the physical properties requirements tabulated in table headed "Rubber Gasket Physical Properties," when tested in accordance with paragraph 5. below:

4. Fabrication. - Rubber gaskets shall be extruded or molded and cured such that any cross section is dense, homogeneous, and free of porosity, blisters, pitting, or other defects.

For gaskets fabricated by molding, maximum permissible flash shall be 0.032 inch, and maximum mold mismatch shall be 0.01 inch.

If a splice is used, splice strength shall be such that 100 percent elongation of that part of the gasket containing the splice results in no visible separation of the splice. While stretched, the gasket shall be rotated a minimum of 180° in each direction to inspect for splice separation. Additionally, all portions of the splice shal' be capable of performing the

## Rubber Gasket Physical Properties

| Property | Gasket type: Ordinary | Gasket type: Petroleum resistant |
|---|---|---|
| Tensile strength, psi, minimum | | |
| Average of three specimens | 2,000 | 1,500 |
| Lowest individual | 1,800 | 1,300 |
| Elongation at break, percent, minimum | | |
| Average of three specimens | 400 | 350 |
| Lowest individual | 375 | 325 |
| Hardness, shore durometer, type A* | 40-60 ±5 | 40-60 ±5 |
| Compression set, percent, maximum | 20 | 20 |
| Properties after air oven aging | | |
| Percent change from original values | | |
| Tensile strength, maximum | -20 | -20 |
| Elongation, maximum | -20 | -40 |
| Hardness, shore A. maximum | +8 | +15 |
| Mass change after water immersion | | |
| Percent, maximum | +5 | +15 |
| Volume change after oil immersion | | |
| Percent, maximum | --- | +80 |

* The nominal value required by the pipe manufacturer shall be between 40-60 shore A points. The variation from the selected value within that range shall be ± 5 shore A points.

bend test with no visible separation. The bend test shall consist of wrapping the portion of gasket containing the splice a minimum of 180° and a maximum of 270° around a rod of diameter equal to the largest cross-sectional dimension of the gasket. No more than two splices shall be made per gasket, and the length of gasket between splices shall be not less than 24 inches.

After fabrication each gasket shall be permanently and clearly marked with manufacturer's name or trademark, pipe size, and year of manufacture. Additionally, petroleum-resistant gaskets shall be permanently marked with a colored stripe, dot, or other identifying mark to distinguish them from ordinary gaskets.

Gaskets shall be stored in as cool a place as practicable and protected from direct sun rays.

5. Testing. - Samples of finished product shall conform to the physical properties requirements specified in paragraph 3., above when tested in accordance with this paragraph. For composite or multi-durometer-type gaskets the test shall be conducted on the softer mating (sealing) portion of the gasket. Except as specified, test procedures and methods shall conform to ASTM standards referenced below.

a. Tensile strength and elongation at break. - ASTM D 412. Test specimens shall be type C dumbbell conforming to figure 1 of ASTM D 412. Specimens may be cut from molded pads or from sections machined from the finished product. Machined gasket sections may be prepared in a jig mounted in the chuck of a lathe. A sharp, thin-cutting knife in the lathe holder shall produce a cut at right angles to the jig face. Cutting site shall be lubricated at all times by a jet of cool water. Prepared sections may be buffed lightly prior to cutting dumbbells.

b. Hardness. - ASTM D 2240.

c. Compression set. - ASTM D 395, method B. Three test specimens shall be cut from three separate gaskets. The standard specimen shall be type 1, of ASTM D 395. An alternate test specimen is allowable if normally used by the gasket manufacturer. The alternate test specimens shall be 3 inches long and shall be placed in a method B compression device 2 inches long with the inner and outer circumferential surfaces in contact with the compression plates. Reference measurement shall be made and specimen compressed 50 percent at the reference point using spacers. Test specimens shall be oven aged for 22 hours at 158 °F (70 °C).

d. Air oven aging. - ASTM D 573 or D 865. Test specimens from ordinary gaskets shall be air aged for 96 hours at 158 °F (70 °C).

(1) Tensile strength and elongation at break. - In accordance with subparagraph a., above.

(2) Hardness. - In accordance with subparagraph 5.b., above.

e. Water aging. - ASTM D 471. Temperature shall be held at 158 °F (70 °C) for 48 hours. Immediately after removal from the water, specimens shall be blotted, and the mass change determined as the average of three specimens.

f. Oil aging. - ASTM D 471. Test specimens shall be immersed in ASTM No. 3 oil for 70 hours at 212 °F (100 °C) and the volume change determined as the average of three specimens.

10-25-91 Revisions: Revised table "Rubber Gasket Physical Properties". Other minor revisions throughout.

## PART B - ELECTRICAL - POWER, CONTROL SYSTEMS AND OPERATING CONDITIONS

## IV-B-01. SUMMARY

The Eastern Arkansas - Grand Prairie Demonstration Project includes an area approximately 40 miles long and 20 miles wide. Within the canal network there will be 18 gated check structures, 57 main canal turnouts, 91 lateral turnouts and approximately 229 road crossings. Water will be furnished to the canal system from the White River by a 1640 CFS (cubic feet per second) pumping station (Major Pumping Station) operated and controlled by a pumping station operator (Pump Operator) and supplimented in the canal system by one fully automated 100 CFS pumping station (Relift Station). The main canal turnouts and lateral turnouts also furnished as part of this project will contain individual gates and pumping units to provide water to specific reaches. The entire canal system made up of gates and pumps (excluding the Major Pumping Station) will be controlled by a Supervisory Control and Data Acquisition (SCADA) system and will be operated by an operator (Watermaster). The operation of the canal system using this SCADA control will allow the system to be controlled by using full automatic or operator assisted (manual) operation, or a combination of both. This system is known as a supervisory automatic or supervisory computer directed control system. The central monitoring station for the main canal control system will be located in the control room of the Major Pumping Station and will be separate from the controls for the pumping station. The control systems for the pumping station and for the entire canal network will be capable of interfacing with each other for future total automatic control. The Pump Operator, Watermaster, and all support personnel will possess a high degree of technical expertise to insure successful canal operations.

The Major Pumping Station will operate as a supply type station with upstream control. The pumping station is a supply oriented system because the amount of water available from the supply (White River) will determine the operation schedule of the pumping station and the canal flow schedule. The control structures and turnouts having gravity flow or pumps located in the canal system will be operated as a supply type system. The system will be controlled by the Watermaster based on real time information of water levels upstream and downstream of the structures and the demands of the water delivery schedule. The control systems for the pumping stations and the canal system will be designed with components requiring low maintenance and ease of operation.

## IV-B-02. Canal Flow Requirements.

The canal flow requirements, or water delivery schedule, will be determined by adding the amount of water required starting at the most downstream pool and progressing upstream to the canal headworks ( the Major Pumping Station). These amounts will be requested by the farmers at least 24 hours in advance of need. The Watermaster will then be able to determine the total amount of water necessary to satisfy all customers. The system will then initiate the water transfer procedures by adjusting the water elevation and flows starting at the canal headworks and progressing down the system to each check structure and turnout. The operator will provide for continuous readjustments of all equipment as needed to maintain the required water flow. The use of the scheduled delivery system also allows the Watermaster the option of requiring the water users to reschedule deliveries if the cumulative water orders exceed the daily, monthly or yearly contractual allotments. The canal water flow will also be a controlled volume or dynamic regulation system capable of responding to a wide range of flow conditions. The controlled volume method of operation based upon real time dynamic conditions requires complex and frequent system changes to the entire canal system and not just conditions in the vicinity of one controlled structure. These complex operations can only be determined by a mathematical model of the canal system. The mathematical model needed to adjust the control equipment to meet the canal demands will be developed as part of the contract for the control system.

## IV-B-03. Control.

Electronic control of all check structures, main canal turnouts, lateral turnouts and pump turnouts will be accomplished using information from upstream and downstream water level sensors. These movements will occur automatically at the structures with set points capable of being remotely changed from the central monitoring station. The sensed information will be interpreted by control algorithms designed to calculate the adjustments required to position the canal check gates to satisfy the actual water requirements. These algorithms represent a set of well defined rules and adjustments that will create solutions to water deliveries in a finite number of steps by using mathematical equations and Boolean logic (a logic system using "and", "or", "if" etc.). Microprocessor equipment will be used to execute the algorithms and perform all necessary logic calculations for automatic control. Each control structure will have this capacity and will be able to control the equipment, either gates or pumps, automatically.

The control system will operate in a closed loop where the operation of gates or pumps is compared to a desired quantity of water and any deviation is fed back into the control system for correction, i.e., feedback control. If the feedback system does not allow a return to equilibrium after initiating a change, the disturbances will oscillate at a constant amplitude or may even increase in amplitude. When reviewing the performance of the control system for stability, the characteristics of the Laplace transform of the canal structures and equipment must be analyzed. This analysis will be performed in conjunction with the mathematical model of the canal system and will be included in the contract for the control system.

All sensor inputs to the controllers will be filtered, i.e., the input signal will not allow any canal water surface wave action due to wind waves and other influences of short disturbances to continuously change gate positions thus decreasing the number of gate movements. In addition, the control scheme will incorporate some deadband and antihunt features to improve stability and prevent short rapid gate movements.

The mode of control, or manner in which the gate system will operate, will be a combination of proportional, integral, and derivative (PID) modes. The proportional control will control the gates using a fixed linear relationship between the desired water elevation and the position of the gates. Proportional control normally has a inherent residual error associated with it and is known as the water level offset. This offset is a sustained deviation of the water level from the setpoint. To correct this offset, the integral or reset mode will be used that provides a restoration of the proportional offset, or to return the water level to its original elevation after a change in flow rates. As soon as a error develops, a gradual and automatic shift begins to bring the input variable to the setpoint value to eliminate the offset error. The third mode of control, derivative or rate of change, will allow for a initially large control response when a deviation from the setpoint occurs. Rate control provides a temporary overcorrection to the system that is proportional to the rate of deviation per unit time. This is necessary because canal systems have a unusually large delay or lag time from time of setpoint deviation to actual water level desired. After the initial large control response, the other modes of control will take effect and set the final gate position using proportional plus reset control.

The main Major Pumping Station will be operator controlled with some automatic systems. In general, the station will contain automatic shutdown of pump motors for pump or motor failures and other normal pumping station conditions. The pumps will be started and stopped manually by the pumping station operator based on water supply and customer demand with provisions for possible future total automatic operation.

The relift station will operate automatically based on the upstream water elevation and will only pump when water is available in the 3200 canal. The relift station will also be capable of local manual control or remote control from the central monitoring station.

## IV-B-04. Water Conveyance System.

The water distribution system will consist of a 1640 CFS main pumping station delivering water from the White River through discharge pipes into a concrete discharge structure and then to a open channel main canal connector system. The main canal system will discharge to either pump or gravity turnouts that will supply water to local farmers. The canal system will maintain water levels within specified maximum and minimum limits to provide predictable service to canal side turnouts and optimize pumping unit start-up to reduce power and maintenance costs.

The system will operate on the principle of balanced pool operation, i.e., the amount of water between each check structure will conform to the criteria of QC1 = QTO1 + QC2 or Pool Inflow = Flow from Turnouts + Pool Outflow. The canal flow type, or how the flow depth changes with respect to distance and time, can be classified as an unsteady, gradually varied flow. All flow changes initiated by changing gate positions at a check structure and by varying the capacity of the pumping plants will create a traveling translatory wave which travels at a greater velocity than the mean canal water velocity. Because of this positive gravity wave in open channels when a gate is opened even a small increment, water flow will begin to increase at points downstream as soon as the leading edge of the translatory wave front arrives. This translatory wave arrives sooner than water supplied by the average flow velocity in the canal. At the same time a negative translatory wave progresses upstream of the gate. Conversely, when a gate closes the opposite occurs. These effects create complex water conditions that require multiple control schemes and will be addressed by the control algorithms and programs associated with the individual site controllers and the main canal control system controller.

## IV-B-05. Gates.

The gates used in the check structures, conduit check structures, main canal turnouts, and lateral turnouts will be roller or slide gates ranging in size from approximately 1.5 feet to 14 feet and will be suitable for irrigation use. The gates will be operated by electric motor with provisions for manual raising and lowering in the event of power or equipment failure. The position of the gates will be monitored by sensors. The gates will normally operate automatically from a pre-programed water elevation setpoint. The gate setpoint will be capable of being changed remotely by the operator (Watermaster) from the central monitoring station or be manually changed at the site should the need arise. The gates on the check structures will also operate in a submerged condition, i.e., the toe of the downstream hydraulic jump immediately downstream of the gate lip will be submerged. The canal check gates will be operated selectively where individual gates are operated independently of other check gates in the canal. In the case of power failure, the gates will either close automatically or will remain in their position, depending on the requirements of the entire canal system.

## IV-B-06. Turnouts.

The canal system will have a total of 57 main canal turnouts and 91 lateral turnouts. The turnouts will be either gravity flow or will contain pumping units. At the turnouts a constant minimum water depth will be maintained as far as practible to provide a steady turnout flow. In the 57 main canal turnouts, a total of 24 will be furnished with pumping units ranging in size from 5 horsepower to 80 horsepower motors. The 91 lateral turnouts will have a total of 38 pumping units also ranging in size from 5 horsepower to 80 horsepower motors. The water level will also be measured upstream and downstream from the turnouts and the water flow rate calculated at the central monitoring station either manually by the Watermaster or by the main central computer.

## IV-B-07. Pumps.

The main pumping station (Major Pumping Station) will contain 4 - 6,000 horsepower and 2 - 1,500 horsepower pumps that will deliver 1640 CFS (cubic feet per second) of water from the White River into the main canal system. These pumps will be controlled at the pump station by a operator (Pump Operator) who will start and stop the pumps, or any combination of pumps, from a master control station. The Watermaster will determine the amount of water available and the amount required by the customers. Each pump will be individually controlled by the operator to satisfy these conditions. The combination of different capacity pumping units will allow for greater diversity and operational flexibility in canal water flow.

The relift pumping station will consist of 5 - 50 horsepower pumps that will deliver 100 CFS (cubic feet per second). The pumping station will operate automatically based on the water elevation upstream of the pumping station.

The main canal turnouts will have a total of 24 pumping units ranging in size from 5 horsepower to 95 horsepower. The lateral turnouts will have a total of 39 pumping units also ranging in size from 5 to 95 horsepower. The pumping units will be equipped with pressure sensors and sensors for pump status "on" and "off". Each pumping unit will be controlled by the operator

(Watermaster) at the central monitoring station. The pumping units will be capable of operation by remote or local manual/automatic control and will also transmit all monitored features at the site to the central monitoring station.

## IV-B-08. Major Pumping Station.

The main pumping station for the project will deliver 1640 CFS (cubic feet per second) of water from the White River into the canal system. The station will consist of four (4) - 6,000 horsepower and two (2) - 1,500 horsepower electric motor driven pumps and will operate independently of the canal control system. The electric motors and all ancillary systems in the pumping station will be supplied power from a electric substation located adjacent to the pumping station. The electric substation will be owned, operated, and maintained by Entergy Services, Inc., with headquarters in Little Rock, Arkansas. The pumping station will have a separate monitoring and control system from the canal control system and will be operated by a operator (Pump Operator) located in the pumping station control room. The operation of the pumping station will be determined by supply conditions in the White River and the demands of the canal system. The normal pumping station parameters will be monitored and/or alarmed as required, i.e., pump low water cutoff, pump and motor bearing temperatures, lubricating system operation, loss of electrical power, position of gates, etc. The final plans and specifications and all electrical engineering services during construction for the Major Pumping Station will be furnished by the U.S. Army Corps of Engineers, North Pacific Division, Hydroelectric Design Center (HDC) as required by Engineer Regulation ER 1110-2-109 and by the Memorandum of Understanding between the U.S. Army Corps of Engineers - Memphis District and the U.S. Army Corps of Engineers - Hydroelectric Design Center (HDC). The U.S. Army Corps of Engineers - Memphis District presently has and will provide future engineering support to HDC during the design and construction of the pumping plant. A more in depth discussion of the electrical systems and power requirements of the Major Pumping Station can be found in Section V of this report.

## IV-B-09. Relift Station.

The relift station will consist of five (5) - 50 horsepower electric motor driven pumps delivering water into canal 3200 at 100 CFS (cubic feet per second) which will supply the northern reaches of the project. The pumping station electric motors and other systems will be supplied power by Entergy Services, Inc., with headquarters in Little Rock, Arkansas. The pumping station will be fully automatic, controlled by water level sensors upstream and will be capable of operating under local manual control or by remote setpoint from the central monitoring station. The pump station will contain sensors for pump(s) status "on" and "off", high and low water in the pump bay(s) and other normal pumping station sensors and alarms. The alarms will register at the central monitoring station and will include motor and pump bearing temperatures, lubrication failures, loss of power, etc.

## IV-B-10. Controllers.

The control system will operate as a supervisory automatic control system with remote set point capability. Each structure with gates and/or pumps will have a controller (commonly called a Remote Terminal Unit - RTU) which will measure various parameters such as upstream and downstream water elevations, position of gate(s) on gated structures, the rate of change of water elevation, pump pressure, and pump status "on" or "off" at turnouts. The controller will be a microprocessor-controlled device and will be capable of performing real time measurements, signal processing, system control and communications of remote field conditions. The controller will operate the structure(s) automatically and/or transmit the data to a central monitoring station for manual operation. In addition, the RTU will transmit all alarm conditions to the central monitoring station. The operator at the central monitoring station (Watermaster) will continuously check the operation and functions at each site and the operator or the controller (if automatic) will calculate water flow rates. The Watermaster will also have the capability of changing the operating parameter(s) remotely from the central station.

The controller will perform the following functions:

a. Measure average water elevation (filtered signal) upstream of the site.
b. Measure average water elevation (filtered signal) downstream of the site.
c. Measure gate(s) position at gated structures.
d. Measure rate of change of average (filtered signal) water elevation.
e. Automatically raise or lower gate(s) at gated structures.
f. Measure pressure in discharge pipe of pumps at turnouts.
g. Monitor the status of pump(s) at turnouts (on-off).
h. Transmit all measured data to the central monitoring station.
I. Accept remote changes in setpoints from the central monitoring station.
j. Accept remote manual control from the central monitoring station.
k. Alarm at the central monitoring station for low or high water elevations, loss of power, intrusion by unauthorized personnel and any failure of equipment.
l. Operate on battery with 120 VAC or solar power (if required) recharge.

## IV-B-11. Central Monitoring Station.

The main central monitoring station (commonly called Headquarters or Master Station) will be located in the 1640 CFS pumping station control room. The central monitoring station will consist of a IBM compatible Pentium class computer with monitor(s) that will run software programs enabling the operator to interface with the system for programming, alarm announcements and acknowledgment, real-time monitoring, supervisory control and data logging. The main canal control system will be furnished with a color video display and will present all information on the canal system to the Watermaster using a system of display screens. The computer and color display will be furnished with back-up units that will be capable of completing all canal control tasks if the main equipment becomes inoperable or is down for maintenance or upgrading.

The central monitoring station will perform the following functions:

a. Provide a real-time monitor of all network activities.
b. Annunciate alarms and provide acknowledgment capability.
c. Record measurement and status data.
d. Provide a interface for system programming.
e. Support multiple monitoring stations (if required).
f. Provide remote manual control of each monitored site.
g. Be capable of using industry standard computer platforms and software.
h. Provide a hardcopy (printer) record of all inputs/outputs.

## IV-B-12. Communications.

The entire monitoring and control system for the canals will be connected both from site to site (as required) and from site to the central monitoring station by radio link. Radio frequency transmissions were chosen over other systems (satellite transmission, direct buried cable, telephone modem, etc.) for simplicity, ease of maintenance, expansion capability, and cost effectiveness. The transmissions will be capable of covering a distance of 20 miles (low power, generally 2 watts) with each controller capable of being used as a repeater to extend the range of transmitted data from the most distant site to the central monitoring station. Power will be supplied to the transmitters by battery with battery recharge either by 120 volts ac or by solar cell at remote sites where it is not practicable to install a normal power line. The data will be sent over dedicated frequencies (mid 400 MHZ range) with each site having a unique coded identification address. It is anticipated that the data will be transmitted at least every 15 minutes. Some RTU's may be hard wired in one location with the final data transmissions sent by radio link to a centrally located RTU or the central monitoring station. The entire communications system will be configured as a radial system for rapid communication, direct control, and numerous data points. The coded communications system will meet all the requirements of telemetry security mandated by DOD for protection of unauthorized access.

A possible future alternative to the proposed radio frequency data transmission is a new technology known as Cellular Digital Packet Data (CDPD). This communication system utilizes existing commercial cellular telephone networks to transmit data and unlike normal cellular telephone calls that are billed by the minute plus a monthly fee, the user is charged only for the amount of bytes transmitted, and the connection remains active all the time. The controllers would require a telephone modem to connect to the existing cellular carrier and would therefore eliminate any local maintenance on the cellular system as is required on the radio frequency system. CDPD uses an idle channel in a existing analog cellular system to provide a connectionless service. When a channel is not being used for voice traffic, it can be used to send and receive packets from the CDPD equipped mobile station. Cellular channels can be shared between voice and data or the cellular carrier can remove some channels from voice service and dedicate them exclusively to data service. CDPD is ideally suited for short and bursty transmission such as remote device monitoring. This type of data transmission is currently not available in Arkansas but is expected to be available in the next several years. The controllers used for the canal system will be capable of using this technology when it becomes available in Arkansas, if desired.

## IV-B-13. Lightning and Surge Protection.

All canal control equipment will be protected from lightning and surges. Protective devices will be installed at the ac power line, the controllers, antenna, and all sensor inputs. The devices will include fuses and MOV's (metal oxide varistors), radio frequency interference filters, and isolation equipment. All equipment and all metallic enclosures will be electrically bonded together and securely grounded. Since the communication devices transmitting the data of the canal system operate on battery power with automatic recharge, the Watermaster will know at all times the condition of the canal gates and pumps. Any power outages can be reported to the power company immediately for repair.

## IV-B-14. Power Sources.

The electric power supply for the Major Pumping Station, for the relift station, and all other electric operated gates and small pumps located throughout the project will be provided by Entergy Services, Inc., located in Little Rock, Arkansas. The size of the electric substation at the main Major Pumping Station will be approximately 25 MVA and for the relift station approximately 300 kVA. The capital costs to the power company associated with the 25 MVA substation are substantial and are estimated to be about $2 million dollars. These costs are normally passed on to the customer as demand charges, customer service fees, a increase in the energy charges, etc.

The power company has stated that any reduction in their construction costs for this large substation may reduce the amount of minimum monthly fees that will be passed on to the customer. Entergy Services, Inc. will retain ownership of the transmission line and substation and will be responsible for the operation and maintenance of the line and all equipment associated with it. The minimum monthly bill charged by the power company will be the **higher** amount of either approximately 2.5% of total power company construction costs **or** the rate schedule minimum. With the estimated construction cost of the substation and transmission line of approximately $2 million dollars, the monthly minimum bill would be roughly $50,000 or the rate schedule minimum. The rate schedule monthly minimum charge is comprised of two items, the normal energy usage plus $2.57 per Kilowatt of the highest demand established during the 12 months ending with the current month. The estimated highest electrical monthly demand for the pumping station is expected to be approximately 15, 000 Kilowatts. During any one month, if the pumping station did not run at all , the lowest monthly minimum rate schedule bill would therefore be 15,000 Kilowatts X $2.57 per Kilowatt or approximately $38,550. This is the absolute lowest monthly electric bill for the pumping station.

The Government may contribute to the power company cost of building a electric transmission line and substation for the Major Pumping Station which will lower the minimum monthly cost of approximately $50,000. Since the minimum rate schedule bill will be $38,550 (even if the pumping station does not run, the demand charge must be paid), it is possible to lower the capital construction cost for the substation and transmission line. This construction cost can be reduced to a amount where the 2.5% of construction costs decreases the $50,000 to $38,550, i.e., reduce the $2 million dollar construction cost to approximately $1.5 million dollars (where 2.5% of $1.5 million dollars would approximately equal the $38,550 rate minimum). This reduction of power company construction costs would require a Government contribution of approximately $500,000 on the front end but would only affect the power bill for one month (December is considered a low or no operation month due to low water demand, low river and/or pumping station maintenance; all other months have pumping operations and would raise those monthly bills above the $38,550 absolute lowest monthly bill). The total savings for that one month would only be $50,000 minus $38,550 or $11,450. Continued discussions with the power company may improve these figures and this is being investigated.

In addition, the power company has provided two power rates for energy usage, one for firm power and one for interruptible power. If interruptible power is chosen, the pumping plant would be required to reduce the electrical load to approximately 1,000 kW upon notice from the power company (usually in a 15 to 30 minute time period). This enforced reduction in electrical load will not allow any of the pumping units to operate. In order to have some degree of reliability for the pumping station, standby electric generators could be installed at the site for use during these periods. A cost analysis of firm power vs. interruptible power plus standby generators will be done by HDC to determine if this approach is economically feasible. At the beginning of this project the use of diesel engines as the main pumping plant power source was questioned by the Arkansas Fish and Game Commission because of the pumping plant location next to the Wattensaw State Game Area. The Commission expressed concern about the noise, diesel smoke and possible contamination of the area by diesel fuel, however, this approach will be reevaluated if found to be economically justified.

## IV-B-15. Control System Contract.

The contract for the control system is expected to be accomplished using a two-step sealed bidding procurement in accordance with Part 14, Subpart 14.5, "Two-Step Sealed Bidding" of the FAR and the Department of Defense Federal Acquisition Regulation Supplement (DFARs). In the first step the Government will initiate a purchase procedure by publishing a Request For Technical Proposal (RFTP) which will outline the requirements of the control system. These requirements will include the controllers, the main master operating station with main computer and display, the type of gate and pump motor control needed, and the development of a mathematical model, including numerical analog studies and analysis, and any other studies necessary such as:

a. Normal operational studies to determine how the canal system will operate from startup to full capacity.
b. Steady state conditions showing typical water surface fluctuation rates compared to drawdown and freeboard allowance.
c. Abnormal operational studies to determine how flow is affected during minor equipment failure, draining the canal, filling the canal system and taking parts of the system out of service for testing or repair.
d. Emergency operation studies to predict optimum response to the most severe operating conditions, as excessive water levels or rapid variation in water levels.
e. A computer modeled study to predict radio signal coverage, showing antenna locations including actual onsite signal strength tests.
f. The type of gate and pump motor control needed to meet the requirements of the canal

system, i.e., single speed motor control or adjustable speed drives.

g. The type of gates needed at each check structure and turnouts, i.e., capable of withstanding reverse head, etc.

h. Any recommendations for control of the canal system that will optimize the operation of the system.

After the Government receives the technical proposals, a evaluation and if necessary a discussion of the proposals will be made. The proposals will be classified as acceptable, unacceptable or reasonably susceptible to being made acceptable. Only acceptable or reasonably susceptible to being made acceptable (if necessary to insure adequate price competition) proposals will be allowed to compete in step two. In step two, those proposals deemed acceptable will submit sealed bids that will be evaluated and an award made using standard sealed bid procedures.

US Army Corps of Engineers

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

# SUPERVISORY CONTROL SYSTEM

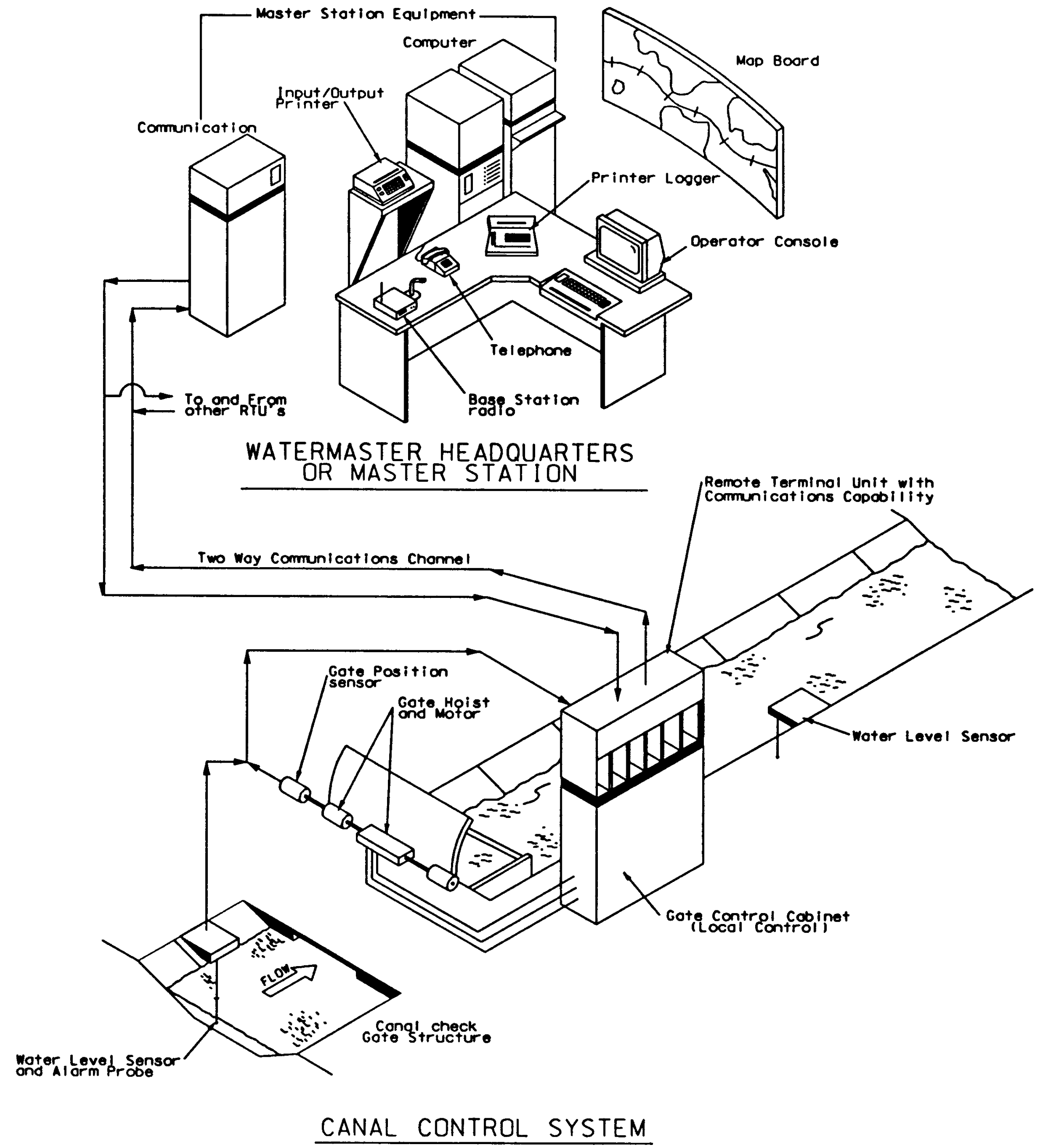


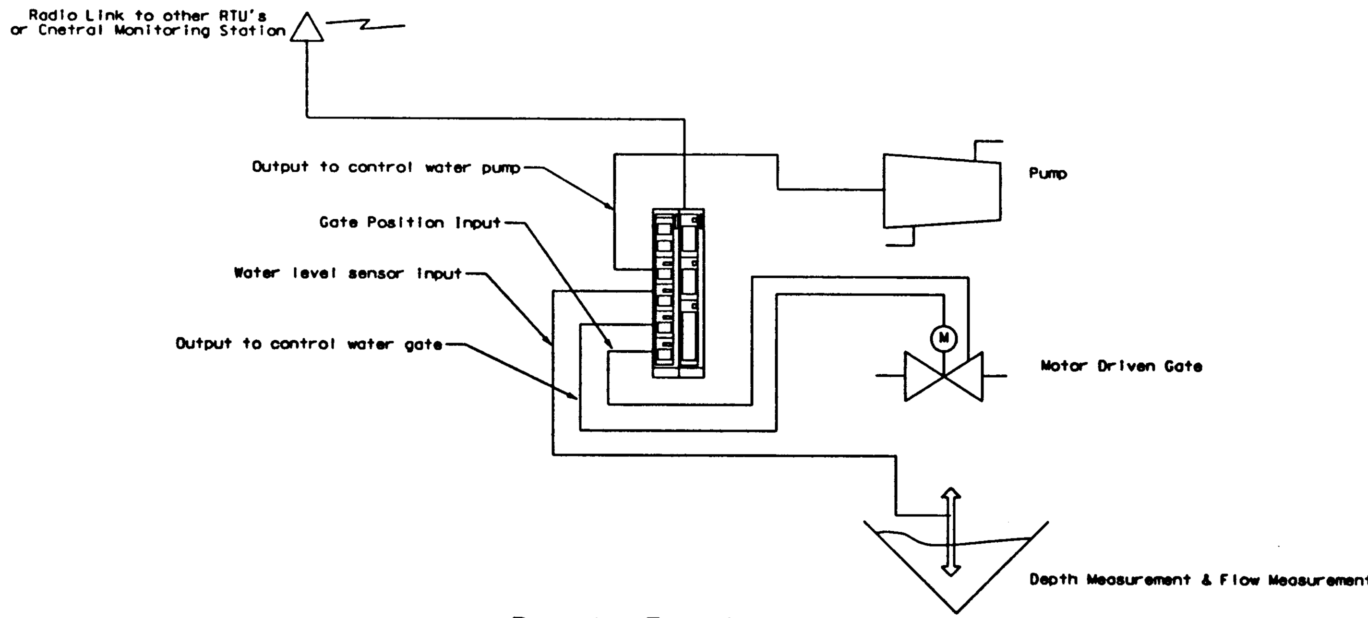

PLATE IV-B-I

US Army Corps of Engineers

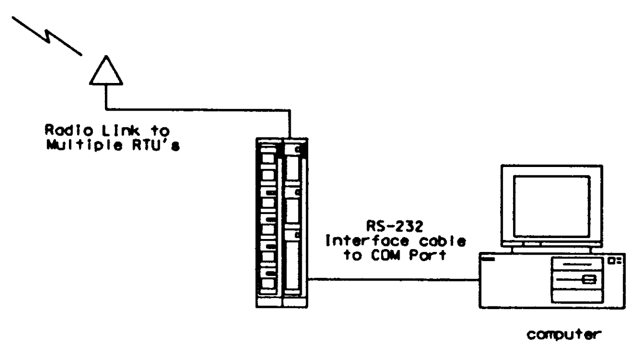
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

# MEASUREMENT AND COMMUNICATION SYSTEM




Remote Terminal Unit
(RTU)




Central Monitoring Station

PLATE
IV-B-II

US Army Corps of Engineers

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MEMPHIS, TENNESSEE

EASTERN ARKANSAS REGION COMPREHENSIVE STUDY
GRAND PRAIRIE AREA
DEMONSTRATION PROJECT

# CENTRAL MONITORING STATION

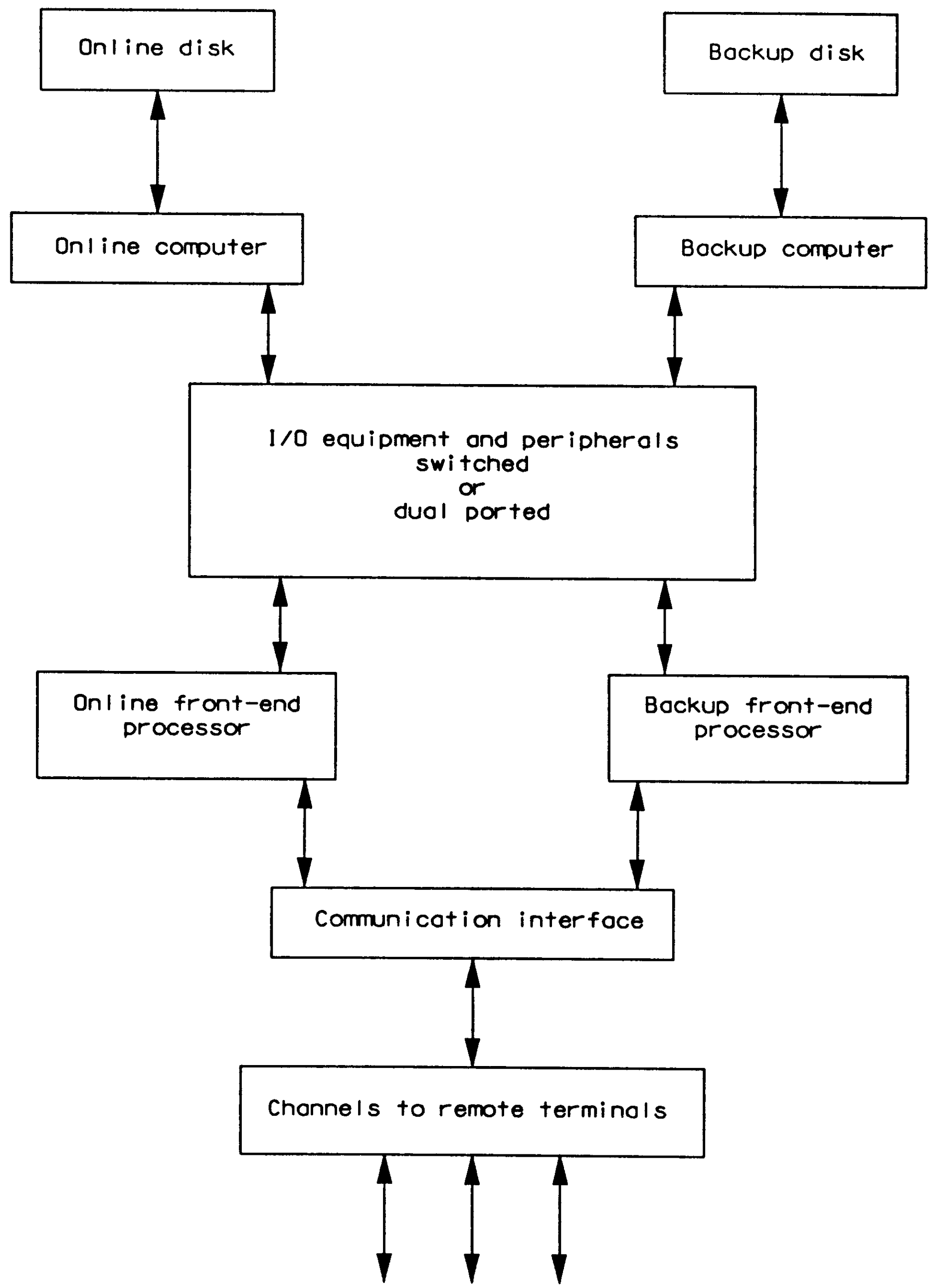



PLATE
IV-B-III

M-1
(M0010000.N91)

# Standard Specifications

for

# Reinforced Concrete Pressure Pipe

November 1, 1991

United States
Department of the Interior
Bureau of Reclamation
Denver Office
Denver Federal Center
Denver, Colorado 80225-0007

CONTENTS

CONTENTS - Continued

STANDARD SPECIFICATIONS FOR
REINFORCED CONCRETE PRESSURE PIPE

1. General. - Reinforced concrete pressure pipe, 12- through 108-inch diameter, shall be designed, manufactured, and tested in accordance with these specifications and contract requirements. Larger sizes require special design. The pipe shall consist of cementitious materials, sand and coarse aggregate, water, and admixtures as elected, reinforced circumferentially and longitudinally with reinforcing steel. Rubber gasket joints capable of providing, when assembled in trenches, a continuous watertight conduit with a smooth and uniform interior surface able to accommodate slight movements of any pipe in the pipeline due to expansion, contraction, settlement, or lateral displacement shall be used.

Contract, as used herein, shall mean the contract which, by reference, these specifications are included in and made a part. Contracting Officer, as used herein, shall mean the person executing the contract on behalf of the Government, and shall include duly-authorized representatives. Contractor, as used herein, shall mean the party entering into the contract with the Government, and shall include subcontractors, suppliers, manufacturers, and agents at all tiers.

Pipe shall not be shipped from the place of manufacture until approved for shipment by the Contracting Officer.

2. Design. - Pipe design shall conform to the requirements of Tables 1 and 2, except alternate designs, as permitted in subparagraph b. below, shall be based on the design criteria specified in subparagraph b. below, and the design criteria contained in the Appendix of these specifications. The computer program RCPIPE1 and the associated user's manual titled "Analysis and Design of Circumferential Reinforcement in Reinforced Concrete Pressure Pipe," are available from the Bureau of Reclamation, Attn D-3521, PO Box 25007, Denver CO 80225.

Pipe designs may be required for hydrostatic heads of 25 to 150 feet, in 25-foot increments, measured to the centerline, and for external loadings of 5, 10, 15, or 20 feet of earth cover, designated A, B, C, or D respectively, measured from the top of the pipe. Pipe class designations used in these specifications correspond to those used in the contract and, as typical examples, shall mean:

A 25: pipe for 5-foot maximum cover and 25-foot maximum head.

D 75: pipe for 20-foot maximum cover and 75-foot maximum head.

B 125: pipe for 10-foot maximum cover and 125-foot maximum head.

Nominal laying length of pipe units shall not exceed:

| Internal pipe diameter (inches) | Nominal laying length (feet) |
|---|---|
| 12 - 18 | 12 |
| 21 - 24 | 16 |
| 27 - 30 | 18 |
| 33 - 36 | 20 |
| 39 - 108 | 24 |

a. Concrete. - To account for material, fabrication, and testing variability, concrete shall be proportioned to have an average 28-day compressive strength (f'c) such that 90 percent of the test cylinders are equal to or greater than the design strength of 4,500 pounds per square inch when tested in accordance with subparagraph 7.e. below. The mixture shall use not less than 564 pounds of cementitious materials per cubic yard of concrete. Concrete ingredients shall conform to the material requirements of these specifications.

b. Design criteria. - Circumferential reinforcement shall be single-cage circular, double-cage circular, or single-cage elliptical, and shall be uniformly spaced with center-to-center spacing, not exceeding 2 inches for wall thicknesses less than 3 inches, and not exceeding the lesser of 4 inches or 0.75 times the wall thickness for wall thicknesses of 3 inches and larger. The clear spacing shall not be less than 1-1/2 inches. Table 1 gives minimum circumferential reinforcement requirements for the various pipe classes based on internal diameter, wall thickness, and type and layers of reinforcement.

Pipe shall not be designed with a wall thickness less than the thinnest wall thickness shown for the diameter and reinforcement type in Table 1 which has a tabulated value for the class involved.

Pipe may be designed with a wall thickness between two wall thicknesses shown in Table 1, provided each wall thickness shown has a tabulated value for the class involved, and for the same type of layers of reinforcement, straight-line interpolation of tabulated values shall be utilized.

Pipe may be designed with a wall thickness greater than shown in Table 1, provided the pipe design is based on, and conforms to, the requirements of these specifications.

Single-cage circular reinforcement shall be positioned between 40 and 50 percent of the nominal wall thickness from the inner surface of the pipe, and the minimum concrete cover shall be 1/2 inch except under the spigot groove. Double-cage circular and elliptical (at horizontal and vertical axes) reinforcement shall be positioned such that the concrete cover conforms to the following and is not less than 1/2 inch except under the spigot groove:

| Wall thickness (inches) | Reinforcement clear cover (inches) |
|---|---|
| 4-3/4 and less | 3/4 ± 1/4 |
| 5 through 6-3/4 | 1 ± 1/4 |
| 7 and greater | 1-1/4 ± 1/4 |

Circumferential reinforcement at each end of a pipe unit shall consist of one complete coil, lapped or welded, positioned not less than 1/2 inch nor more than 1 inch from the end of the pipe unit.

Where joint construction requires the use of a bell, the minimum circumferential reinforcement for the bell shall be in accordance with Table 2.

c. Longitudinal reinforcement. - Longitudinal reinforcement shall be provided sufficient to assemble circumferential reinforcement into a cage capable of retaining design shape during pipe fabrication. Longitudinal reinforcement shall extend the full length of the pipe, shall be uniformly spaced with center-to-center spacing, measured circumferentially, not exceeding 42 inches, and shall consist of not less than four individual bars or rods. Minimum concrete cover shall be 1/2 inch except under the spigot groove.

Where joint construction requires use of a bell, longitudinal reinforcement for the bell shall be, as a minimum, the same number of bars or rods as used in the pipe barrel which may be extensions of the barrel reinforcement, spliced to the barrel reinforcement, or overlapping barrel reinforcement in accordance with details shown on Figures 3 through 6.

d. Joints. - A rubber gasket shall be the sole element of the joint depended upon to provide watertightness. Rubber gaskets shall be solid gaskets of circular cross section. The gasket shall be confined in an annular space formed by the bell or bell ring and a groove in the spigot end of the pipe or spigot ring or by shoulders on the bell and spigot ends of the pipe in such a manner that slight movement of the pipe or hydrostatic pressure cannot displace the gasket and so that when the joint is assembled, the gasket is compressed to form a watertight seal. Joints shall be designed so that the gasket will not be required to support the weight of the pipe. Joints shall be one of the following types:

(1) R-1. - Steel band or sleeve with two rubber gaskets, details conforming to Figure 1. Band or sleeve shall have flared ends to facilitate entrance of gasket, and be a true cylinder of such length to provide a minimum A distance of 3/4 inch at normal joint closure position. Band or sleeve, spigot, gasket, and gasket grooves shall be

sized and proportioned to meet the requirements of subparagraph (4) below for R-4 joints.

(2) R-2. - Steel bell ring and steel structural shape spigot ring, details conforming to Figure 2. Bell ring shall be flared at one end to facilitate entrance of gasket, may be tapered at other end, and shall be a true cylinder of such length to provide a minimum A distance of 3/4 inch at normal joint closure position. The steel bell and spigot rings, gasket, and gasket grooves shall be sized and proportioned to meet the requirements of subparagraph (4) below for R-4 joints.

(3) R-3. - Concrete shoulder on bell and spigot ends of pipe, details conforming to Figures 3 and 4. Leading edge of bell shall be chamfered or rounded to facilitate entrance of gasket. Bell, spigot, and gasket shall be so sized that gasket shall not be stretched more than 20 percent of unstretched length when seated on spigot, and when outer surface of spigot and inner surface of bell come in contact at some point, deformation of gasket shall not exceed 40 percent at point of contact, nor be less than 15 percent at any point. Maximum gasket deformation shall be calculated using minimum spigot shoulder height, maximum stretched gasket diameter, and at the point where spigot shoulder height is measured. Minimum gasket deformation shall be calculated using maximum spigot shoulder height, maximum bell diameter, minimum spigot diameter, minimum stretched gasket diameter, and at the point where spigot shoulder height is measured. Stretched gasket diameter shall be calculated in accordance with subparagraph (4) below. Joint shall be designed, including practicable laying allowance between end of spigot and shoulder of bell, to provide a minimum A distance of 3/4 inch at normal joint closure position.

(4) R-4. - Formed gasket groove in spigot end, details conforming to Figures 5 and 6. Leading edge of bell shall be chamfered or rounded to facilitate entrance of gasket. The minimal cross-sectional area of the annular space for gasket, with joint in normal concentric closure position, shall not be less than the cross-sectional area of gasket calculated using the maximum stretched cross-sectional diameter. Minimal cross-sectional area of annular space for gasket shall be calculated for minimum bell diameter, maximum spigot diameter, minimum groove width at spigot surface, and minimum groove depth.

If average stretched cross-sectional area of gasket is less than 75 percent of the average cross-sectional area of annular space for gasket, as calculated below, gasket shall not be stretched more than 20 percent of unstretched length when seated in groove; if gasket stretched cross-sectional area is 75 percent or more of average cross-sectional area of annular space for gasket, gasket stretch shall not exceed 30 percent. The average cross-sectional area of annular space for gasket, with joint in normal concentric closure position, shall be calculated for average bell diameter, average spigot diameter, average groove width at spigot surface, and average groove depth.

If average stretched cross-sectional area of gasket is less than 75 percent of the average cross-sectional area of annular space for gasket, as calculated above, gasket deformation shall not exceed 40 percent at point of contact, nor be less than 15 percent at any point, when outer surface of spigot and inner surface of bell come in contact at some point; if gasket average stretched cross-sectional area is 75 percent or more of the average cross-sectional area of annular space for gasket, gasket deformation shall not exceed 50 percent at point of contact nor be less than 15 percent at any point.

Maximum gasket deformation shall be calculated using maximum groove width, minimum groove depth, maximum stretched gasket diameter, and at groove centerline. Minimum gasket deformation shall be calculated using maximum groove width, maximum bell diameter, minimum spigot diameter, maximum groove depth, minimum stretched gasket diameter, and at groove centerline. Stretched gasket diameter shall be calculated from:

$$Ds = Dd/(1 + x)^{1/2}$$

where:

$Ds$ = stretched gasket diameter.
$Dd$ = unstretched maximum or minimum gasket diameter.
$x$ = percent stretch divided by 100.

The computer program PIPEJT1 and the associated user's manual titled "Analysis of Round Rubber Gaskets in Pressure Pipe," are available from the Bureau of Reclamation, Attn D-3521, PO Box 25007, Denver CO 80225.

Joint shall be designed, including practicable laying allowance between end of spigot and shoulder of bell, to provide a minimum A distance of 3/4 inch at normal joint closure position.

3. Submittals. - Submittals shall be in accordance with these specifications and the paragraph in section 1.1 of the contract entitled "Submittal Requirements." The Contractor shall be responsible for the accuracy of all submittals. Submittals shall be submitted at least 45 days prior to the beginning of pipe fabrication.

The following item (subparagraph a.) shall be submitted, for approval, to Bureau of Reclamation, Attn D-3120, PO Box 25007, Denver CO 80225 in accordance with the referenced contract paragraph:

a. Pipe design. - For alternate designs, data as shown in Tables 1 and 2, including diameter, pipe class, wall thickness, type, layers, spacing, and area of reinforcement shall be submitted for each design proposed.

The following item (subparagraph b.) shall be submitted, for approval, to Bureau of Reclamation, Attn D-3731, Building 56, Entrance S-6, Denver Federal Center, Denver CO 80225:

b. Aggregate. - If aggregate is to be obtained from a deposit not previously tested and approved by the Contracting Officer, a 200-pound sample of the untested aggregate shall be submitted for testing. For coarse aggregate, one 200-pound sample shall be submitted for each nominal size fraction of coarse aggregate proposed for use.

The following items (subparagraphs c., d., e., f., and g.) shall be submitted, for approval, to the Project Construction Engineer, Project Manager, or other designated field representative in accordance with the referenced contract paragraph:

c. Cementitious materials. - Identification of producers and mills from which shipments are to be made; status of producers and mills regarding prequalification for the specified material in accordance with Department of Army Regulation No. ER-1110-1-2002; whether materials are to be ordered in bulk or bags; and purchase order number(s), contract number, or other information identifying the cementitious materials.

For non-prequalified producers, cementitious materials will be Government tested in accordance with subparagraph 7.a. below.

Each shipment of cement or pozzolan shall be accompanied by shipping documents containing:

(1) A mill test report and certification of conformance with these specifications.

(2) Type or class of material, including any optional limitations or requirements specified.

(3) Manufacturing location, date(s), and lot (bin) number.

(4) Date of shipment and quantity shipped.

d. Admixtures. - Manufacturers and specific brand names of all admixtures proposed for use. The Contractor will be informed as to whether certification and data only, or also a sample shall be submitted for each admixture.

The Contractor shall submit, for testing as required and approval, certification, data, and as required, a 1-quart sample for each admixture proposed for use. Certification shall include name and type of admixture, and conformance with appropriate ASTM standard. Data shall include manufacturer's product description, instructions, recommended dosage, acid-soluble chloride content, and precautions for use. If available, data shall also include independent laboratory test data demonstrating ASTM standard conformance.

e. Quality assurance. - A complete description of the Contractor's proposed quality control program, including policies, measures, and procedures.

f. Gaskets. - Gasket data in accordance with Reclamation's Standard Specifications No. M-15, "Standard Specifications for Rubber Gaskets for Joining Pipe."

g. Pipe shipment. - Written notice that finished pipe units are ready for shipment in accordance with subparagraph 4.c.

The following item (subparagraph h.) shall be submitted, for information, to the Bureau of Reclamation, Attn D-3120, PO Box 25007, Denver CO 80225 in accordance with the referenced contract paragraph:

h. Joint design. - Completed Joint Data Forms (fig. 7) for each type and size of joint proposed for use.

4. Quality assurance. - Quality assurance shall be in accordance with the requirements of subsection I.3 of the contract entitled "Quality Assurance," and with the requirements of these specifications.

If the results of production indicate that proper quality control procedures are not being consistently utilized, as evidenced by manufacture of defective pipe units, failure of pipe units to pass inspection or testing requirements, plant shutdowns due to equipment or process failure, or similar conditions, or if there are significant changes in materials, mix proportions, or production procedures, further approval of pipe units or repaired pipe units may be suspended in whole or in part at the discretion of the Contracting Officer. Such suspension will be effective until the Contractor demonstrates substantial improvement in quality control procedures and production results.

a. Contractor's quality control. - In accordance with the clause in subsection I.3 of the contract entitled "Inspection of Construction," the Contractor shall be responsible for providing quality control measures to ensure compliance of the pipe with contract requirements. The Contractor shall institute necessary and appropriate quality control procedures to ensure that all pipe units produced conform to the requirements of these specifications. Records shall be kept of pipe design details for each size and class of pipe to be furnished, and of quality control inspections and tests made during the production of pipe under these specifications. These records shall be kept for the duration of the warranty period of the pipe, and shall be made available to authorized representatives of the Contracting Officer upon request.

The Contractor shall also obtain and deliver to an authorized representative of the Contracting Officer certified test results of physical tests prescribed in the ASTM standards under which reinforcement is furnished, and within 24 hours of testing, results of tests specified in paragraph 7. below.

b. Government inspection. - Government inspection will be in accordance with the clause in subsection I.3 of the contract entitled "Inspection of Construction," and with these specifications.

In addition, each pipe unit will be examined by an authorized representative of the Contracting Officer to determine conformance with the following requirements:

(1) Pipe shall have smooth cylindrical interior surfaces free from scaling, or loose, weak areas, except areas of depth 1/8 inch or less which can be brushed to a firm surface. Interior surfaces shall also be free from float rock, clay balls, wood particles, or other light materials.

(2) Concrete surfaces of bells and spigots in the gasket bearing area, and adjacent surfaces that may come into contact with the gasket within joint movement range shall be free from defects. Repairs which have been performed in the area shall be in accordance with subparagraph 6.j. below, and shall be free from defects.

(3) Exterior surfaces shall be free from surface defects such as honeycomb, open texture, blisters, and drummy areas more than 1/4 inch in depth.

(4) Pipe units shall be free from longitudinal or circumferential cracks, unless the unit passes the hydrostatic test of subparagraph 7.g. below.

(5) Pipe and joints shall be within the dimensional tolerances required by these specifications and the submitted Joint Data Form.

c. Approval. - Approval of the pipe at the place of manufacture will be based on the inspection and testing requirements of these specifications.

At least 48 hours prior to shipping, the Contracting Officer shall be notified that finished pipe units are ready for shipment. The Contracting Officer will inspect the pipe units, and approve for shipment those meeting the requirements of these specifications.

d. Rejection. - Pipe that fails to meet the requirements of these specifications will be rejected. In the event of disagreement regarding rejection at the place of manufacture, the Contractor shall file written notice within 1 week of the rejection action, and before disposal of the rejected pipe to preserve evidence of the pipe condition.

e. Further inspection. - After shipment, further inspection of pipe units will be in accordance with the clause in subsection I.3 of the contract entitled "Inspection of Construction."

5. Materials. -

a. Cementitious materials. - Cementitious materials used in pipe fabrication shall be in accordance with the contract requirements. Immediately upon receipt at the jobsite, bulk cementitious materials shall be stored in dry, weathertight, properly ventilated bins until batched. Bins shall be emptied and cleaned when so directed, however, intervals between cleanings will normally not be less than 6 months.

b. Water. - Water used in concrete, cement mortar, and concrete curing operations shall conform to contract requirements and the following:

(1) Total dissolved solids. - (ASTM D 1888, method A): less than 1,000 milligrams per liter.

(2) Chloride as chloride ion. - (ASTM D 512, method - all): less than 500 milligrams per liter.

(3) pH. - (ASTM D 1293, method - both): greater than 6.5.

c. Admixtures. - Admixtures, if used, shall be of uniform consistency and quality, and shall conform to the following:

(1) Air-entraining. - ASTM C 260; neutralized vinsol resin formulation shall be used with type F or G chemical admixture; amount used shall be such that total air will not exceed 5 percent, by volume, of concrete when discharged from mixer.

(2) Chemical. - ASTM C 494, types A, D, F, or G.

Admixtures shall be maintained at uniform strength of solution, and shall be batched separately in liquid form in dispensers capable of measuring at one time the full quantity of the admixture required for the batch. Measurement shall be by weight or volume, and dispensers shall be constructed and located such that measuring can be observed by the plant operator via a visual gauge. Each admixture shall be discharged separately into the mix water as the water is being discharged into the mixer.

d. Sand. - Sand shall be natural or crushed sand, or a combination, and shall consist of clean, hard, dense, durable, uncoated rock particles with a maximum 3/16-inch size, well graded in conformance with ASTM C 33. Sand shall be obtained from an approved source, and shall conform to the following quality requirements:

(1) Deleterious substances. -

| Deleterious substance | Maximum percent, by weight |
|---|---|
| Materials finer than 75 micrometers (No. 200) sieve (ASTM C 117): | |
| Natural sand | 3 |
| Crushed sand | 3* |
| Lightweight particles (ASTM C 123 using zinc chloride solution) | 2 |
| Clay lumps and friable particles (ASTM C 142) | 1 |
| Total of other (such as mica, coated particles, soft flaky particles, loam) | 2 |
| Sum of all deleterious substances: | |
| Natural sand | 5 |
| Crushed sand | 7 |

* If finer material is fracture dust (stone flour), essentially free of clay or shale, limit shall be 5 percent.

(2) Organic impurities (ASTM C 40). - Color no darker than specified standard.

(3) Soundness by use of sodium sulfate (Reclamation's "Concrete Manual," Designation 19). - Eight percent, maximum, weighted average loss, by weight, after 5 cycles.

(4) Specific gravity (ASTM C 128, saturated, surface-dry basis). - Minimum 2.60.

e. Coarse aggregate. - Coarse aggregate shall be natural gravel or crushed rock, or a combination, and shall consist of clean, hard, dense, durable, uncoated rock particles, well graded in conformance with ASTM C 33 and the size number selected. The size number selected shall be the largest maximum size aggregate practicable for pipe fabrication, and shall be No. 7 (1/2-inch nominal size) or larger. Coarse aggregate shall be obtained from an approved source and shall conform to the following quality requirements:

(1) Deleterious substances.

| Deleterious substance | Maximum percent, by weight |
|---|---|
| Materials finer than 75 micrometers (No. 200) sieve (ASTM C117) | 1/2 |
| Lightweight particles (ASTM C 123 using zinc chloride solution) | 2 |
| Clay lumps and friable particles (ASTM C 142) | 1/2 |
| Total of other | 1 |
| Sum of all deleterious substances | 3 |

(2) Resistance to degradation by abrasion and impact (ASTM C 131). - Ten percent, maximum, loss of weight after 100 revolutions; 40 percent, maximum, loss of weight after 500 revolutions.

(3) Soundness by use of sodium sulfate (Reclamation's "Concrete Manual," Designation 19). - Ten percent, maximum, weighted average loss, by weight after 5 cycles.

(4) Specific gravity (ASTM C 127, saturated surface-dry basis). Minimum 2.60.

f. Reinforcement. -

(1) Steel wire. - ASTM A 82 or A 496.

(2) Steel bars or rods. - ASTM A 615, grade 40.

(3) Welded wire fabric. - ASTM A 185 or A 497.

g. Steel joint rings. - Steel sheet and strips used for bell rings shall have a minimum elongation at rupture of 15 percent in a 2-inch gauge length, and shall meet the requirements of ASTM A 570 or A 569, except that for ASTM A 569 steel, the maximum carbon content shall be 0.25 percent. Special shapes for spigot rings and steel plate for bell rings shall meet the requirements of ASTM A 663, grade 60; ASTM A 575, grade 1012 or 1015; ASTM A 576, grade 1012 or 1015; ASTM A 675, grade 70; or ASTM A 36.

h. Rubber gaskets. - Rubber gaskets shall be circular cross section, O-ring gaskets in accordance with Reclamation's Standard Specifications No. M-15, "Standard Specifications for Rubber Gaskets for Joining Pipe." The shore durometer, type A, shall be in the range of from 35 to 50 for type R-1, R-3, and R-4 joints and 35 to 65 for type R-2 joints. The above range includes the allowable variation defined in the Standard Specifications for Rubber Gaskets for Joining Pipe.

6. Fabrication. -

a. Tolerances. -

(1) Diameter. - The maximum variation (plus or minus) in the internal diameter shall not exceed:

| Diameter of pipe (inches) | Maximum variation (plus or minus) (inches) |
|---|---|
| 12 through 21 | 1/4 |
| 24 through 36 | 5/16 |
| 39 through 51 | 3/8 |
| 54 through 69 | 1/2 |
| 72 through 84 | 5/8 |
| 84 through 108 | 3/4 |

(2) Wall thickness. - At any location on pipe, shall not be less than 95 percent of the design wall thickness.

(3) Joints. - Joint tolerances shall be those shown for the joint design on the Joint Data Form.

(4) End squareness. - Pipe ends shall lie in planes perpendicular to the longitudinal centerline of the pipe, except for bevel-end pipe used for bends. Spigot ends shall be true to such plane within plus 0 inch, minus 1/4 inch, and bell ends within plus or minus 1/4 inch. Pipe ends of bevel-end pipe shall be true to the bevel plane within the above tolerances.

(5) Length. - Finished pipe length shall not deviate from design length (plus or minus) by more than 1/2 inch for any length of pipe.

(6) Inside offset. - When laid and joined in trench, maximum offset on the inside at any joint shall not exceed 0.75 percent of the inside diameter of the pipe or 1/2 inch, whichever is less.

(7) Bells and spigots may have local deviations less than 1/16 inch for pipe diameters less than 48 inches and less than 1/8 inch for pipe diameters equal to or greater than 48 inches.

b. Forms. - Forms shall be made with butt, bevel, or lap joints, and shall be gasketed and sufficiently tight to prevent leakage of mortar. Forms shall be braced and sufficiently stiff to withstand, without detrimental deformation, all operations incident to the placement and compacting of concrete and other pipe manufacturing processes. Forms shall be cleaned, oiled, and free of debris before each filling. Forms and end rings shall be constructed and maintained to permit stripping from the pipe unit without damage to pipe surfaces. Forms and end rings shall be accurately fabricated and assembled so that fabricated pipe units consistently comply with required dimensional tolerances.

c. Reinforcement. - Circumferential reinforcement shall be properly sized and spliced by lapping or welding. Lap splices shall be in accordance with American Concrete Institute "Building Code Requirements for Reinforced Concrete" (ACI-318), except lap length of splices for plain bars and wire shall be twice that required for deformed bars and wire. Welded splices shall develop a tensile strength of not less than 50,000 pounds per square inch based on the nominal area of the bar or wire being welded, and shall be in accordance with applicable requirements of American Welding Society "Structural Welding Code Reinforcing Steel" (AWS D1.4).

Circumferential reinforcement shall be properly spaced and fastened to longitudinal reinforcement by welding or tying each hoop to each longitudinal bar or rod. Welding shall be in accordance with applicable requirements of AWS D1.4, and circumferential reinforcement at the welded intersection shall develop a tensile strength of not less than 50,000 pounds per square inch based on the nominal area of the bar or wire being welded. Reduction in area of circumferential reinforcement at welded intersections shall be minimized.

Each completed reinforcement cage shall be identified according to pipe diameter, layer, and pipe class.

Steel spacer bars, chairs, or other approved spacing and support systems shall be provided to locate and maintain reinforcement cages in forms during the placement and consolidation of concrete. Spacer bars or chairs or other systems extending to finished concrete surfaces shall be plastic coated or made corrosion resistant in an approved manner.

d. Bell and spigot rings. - Bell and spigot rings shall be expanded by a press beyond the elastic limit of the material to ensure accurate sizing.

e. Concrete placement. - Concrete shall be transported and placed so as to prevent segregation of concrete materials and displacement or distortion of steel reinforcement and forms. Temperature of the concrete mixture shall not be less than 40 °F or more than 90 °F at the time of placement.

Concrete may be placed in the pipe forms by the centrifugal method or in vertical forms. For centrifugally spun pipe, the concrete slump shall be a maximum of 1-1/2 inches.

Concrete for use in vertical forms may be either dry cast or wet cast. The dry-cast concrete shall be no-slump (0 inches). Consolidation shall be achieved by use of a vibratory table, the packerhead method, or the tamping method. If the vibrating table is used, the minimum operating frequency shall be 3,600 vibrations per minute. Wet-cast concrete shall be consolidated by form vibrators positioned around the form perimeter so that a minimum frequency of 8,000 vibrations per minute is imparted to the form.

Each pipe unit shall be continuously vibrated when concrete is entering the forms; however, over-vibration shall be avoided when concrete is not entering, particularly in the upper end and when forms are full. Concrete may be revibrated briefly as late after casting completion, as concrete can again be made plastic. The free surface on the upper end shall be troweled to a uniform, smooth, flat finish.

f. Curing. - Each pipe unit shall be cured by an approved process until the concrete reaches a minimum compressive strength of 4,000 pounds per square inch. Curing shall commence within 4 hours after completion of casting. Prior to reaching the design strength (f'c), pipe shall not be exposed to temperatures below 30 °F, nor to temperatures between 30 and 40 °F for more than 4 hours. The curing process may be interrupted for a period not to exceed 4 hours.

(1) Accelerated curing. - Pipe shall be cured in an enclosure suitable for controlling and maintaining temperature and moisture conditions. The enclosure shall allow full circulation of the curing environment around the inside and outside of the pipe, and circulation shall be such that the maximum temperature differential between any two locations does not exceed 20 °F. The enclosure shall be instrumented with two time-temperature recorders, one in the upper level and one in the lower level, and, if relative humidity is controlled, with a time-relative humidity recorder. Data from these recorders shall be made available to authorized representatives of the Contracting Officer upon request.

Exposed surfaces of the pipe shall be kept continuously wet, or the relative humidity within the enclosure controlled. Continuous wetting may be by steam, fog, mist, or other approved means; however, moisture shall not impinge directly upon exposed surfaces to the extent surface damage results. Relative humidity, if controlled, shall not be less than 90 percent when the average air temperature in the enclosure is less than 110 °F, and shall not be less than 95 percent when the average air temperature in the enclosure is 110 °F or more.

The average air temperature within the enclosure shall not be raised above 100 °F by external heat source within 4 hours after the pipe has been cast. Thereafter, average air temperature shall be maintained between 90 and 150 °F for the required curing period, except for permitted interruptions. Rate of temperature rise shall not exceed 30 °F per hour. Rate of temperature fall shall not exceed 40 °F per hour until the concrete surface temperature is within 20 °F of the outside ambient air temperature.

(2) Water curing. - Pipe shall be cured by covering with water-saturated material, by a system of perforated pipes, sprinklers, porous hose, or other approved method which keeps exposed surfaces of the pipe continuously wet for the required curing period, except for permitted interruptions.

g. Joints. - For pipe with R-1 joints, the steel band or sleeve and one rubber gasket shall be installed on one end of the pipe. The band or sleeve shall then be covered with reinforced mortar in accordance with the details of Figure 1. Mortar coating may be applied by pneumatic process, hand placing, or other approved method.

For pipe with R-1 or R-2 joints, portions of steel bands or sleeves and steel bell and spigot rings exposed on the completed pipe shall be thoroughly cleaned of corrosion and foreign matter, and shall be protected from corrosion prior to pipe installation by an approved coating.

h. Marking. - Each pipe unit shall be clearly and permanently marked on the interior surface with:

(1) Size and class conforming to Table 1 designations.

(2) Name or trademark of pipe manufacturer.

(3) Date of manufacture and number in sequence of production.

(4) Type of cement and class of pozzolan if used.

Pipe with elliptical reinforcement shall have both ends of the minor axis of the reinforcement appropriately marked inside and outside on both ends of the pipe unit.

Bevel-end pipe shall be marked inside and outside showing short and long sides and field top.

i. Storage and handling. - Pipe shall not be stored under conditions which would cause injurious drying of concrete or mortar. Whenever necessary, or when determined by the Contracting Officer, to prevent cracking or other objectionable effects of drying at any time prior to laying, pipe shall be adequately protected by means of shelter, application of water, or both.

Pipe shall not be dropped or subjected to jarring, impact, or other treatment which might crack the shell or damage pipe or joints.

The method used to support and secure pipe units during storage, transportation, and preparation for shipment shall be subject to approval of the Contracting Officer.

j. Repair. - Individual pipe units may be repaired when defects are the result of an imperfection in pipe manufacture or accidental damage during handling, and the defects do not subject the pipe unit to rejection as specified in subparagraph 4.d. above. Repairs shall be by approved methods in accordance with Reclamation's Standard Specifications No. M-47 "Standard Specifications for Repair of Concrete." Repairs shall be sound and properly finished and cured, and the repaired pipe shall conform to the requirements of these specifications, including dimensions and tolerances. Hydrostatic testing of repaired pipe may be required if deemed necessary by the Contracting Officer, and such testing shall be at no additional cost to the Government.

7. Testing. - The Contractor shall provide all pipe units, materials, equipment, and labor necessary for performing the required tests at no additional cost to the Government. Test results shall be furnished in accordance with subparagraph 4.a.

a. Cementitious materials. - If cement or pozzolan is to be supplied by a producer not prequalified for the specified material, the cement or pozzolan shall be sampled and stored in sealed silos at the place of manufacture or other approved location, and will be tested by the Government for compliance before it is shipped. Sampling, testing, and approval will be in accordance with Department of Army Regulation No. ER-1110-1-2002.

b. Aggregate. - Approval of deposits shall not be construed as approval of all or any specific materials taken from the deposits, and the specified quality of all such materials shall remain the responsibility of the Contractor. The Contracting Officer reserves the right to test sand or coarse aggregate during manufacture of pipe and, if required, such facilities as may be necessary for procuring representative samples for such testing shall be provided by the Contractor.

c. Joint rings and reinforcement. - Physical tests as prescribed in applicable ASTM standards shall be performed on steel used for the joint rings and reinforcement used in pipe fabrication. Tests may be performed at the mill or pipe plant at the Contractor's option.

If welding of reinforcement is done, two strength tests of welded splices and two strength tests of circumferential reinforcement at welded intersections shall be performed during each 5 days of production. If problems occur, the testing frequency shall be increased as determined by the Contracting Officer.

d. Chloride content. - The acid-soluble chloride content of the mix shall not exceed 0.20 percent of the weight of cementitious material (ASTM C 114).

e. Concrete strength. - The Contractor shall monitor and verify 28-day design compressive strength using 6- by 12-inch cylindrical concrete test specimens made from a single batch of concrete during each working shift. Where the strength of 6- by 12-inch concrete test cylinders exceeds the capacity of the normal field-testing machine, other test cylinder dimensions will be permitted with correction for size of cylinder when approved by the Contracting Officer. Test specimens for concrete that can be consolidated by rodding or internal vibration shall be prepared, laboratory cured, and tested in accordance with ASTM C 31 and C 39, and test results shall be such that:

(1) The average of all sets of three consecutive strength tests shall not be less than 4,500 pounds per square inch.

(2) No individual strength test (average of two cylinders) shall be less than 4,000 pounds per square inch.

Test specimens for concrete that cannot be consolidated by rodding or internal vibration may be prepared using external vibration and a surcharge, or centrifugal spinning that simulates the pipe manufacturing process, when the centrifugal process is used for making the pipe.

Consolidation by external vibration and a surcharge shall be done by the following procedure: simultaneously, use external vibration (8,000 vibrations per minute) to fill the 6- by 12-inch cylinder in 3-inch lifts and a 10-pound cylindrical surcharge. The surcharge should have a diameter of 5-3/4 inches. Consolidation shall be continued until the mortar begins to ooze around the bottom of the surcharge. Specimens prepared in this manner shall be tested and meet the compressive strength criteria cited above.

Consolidation by centrifugal spinning shall be done by the following procedure: centrifugally cast in 6- by 12-inch steel molds spun about their longitudinal axes at a speed that will simulate compaction of concrete in the pipe to produce a spun-cylinder wall thickness of at least 1-1/2 inches. The net concrete cross-sectional area of the hollow cylinder shall be used to determine the compressive strength. Specimens prepared in this manner shall be tested in accordance with ASTM C 39, and test results shall be such that:

(3) The average of all sets of three consecutive strength tests shall be not be less than 6,000 pounds per square inch.

(4) No individual strength test (average of two cylinders) shall be less than 5,500 pounds per square inch.

Additional test specimens may be required if uniform or adequate concrete strengths are not obtained.

Requests to use test specimen sizes other than specified or other deviations shall be submitted for approval.

f. Curing period. - The period required for curing shall be determined by the Contractor using concrete test cylinders made in accordance with the above provisions and tested in accordance with ASTM C 39. Test cylinders shall be cured with the pipe units, and shall be tested in pairs at appropriate time intervals during the curing cycle to establish the time required for the pipe units to attain a compressive strength of 4,000 (5,500 for centrifugally cast cylinders) pounds per square inch. Test cylinders shall be tested as soon as practicable after removal from the curing environment and while still in the moisture condition of the curing environment.

At the start of manufacturing, and thereafter with any significant change in curing process or concrete mixture proportions, six test cylinders shall be made from a single representative batch of concrete.

Once the curing period has been established, three test cylinders per batch from each of two different batches during each working shift shall be made. One cylinder from each of the two batches shall be tested, and both shall test 4,000 (5,500) pounds per square inch, or greater, to permit removal of represented pipe from curing. If either cylinder tests less than 4,000 (5,500) pounds per square inch, curing shall be continued and a second pair of cylinders shall be tested after additional curing with test requirements the same as for the first pair.

g. Hydrostatic. - The Contractor shall perform hydrostatic pressure tests on 2 percent, but not less than two pipe units, of each size and class of pipe manufactured during each test period. Test period, as used herein, shall mean a number of consecutive working days, and the number shall be the number of days the pipe plant is normally operated in a calendar week. Test period shall include plant shutdowns not exceeding 24 hours. Test period may be reduced if deemed necessary by the Contracting Officer. Test period may be increased to 2 calendar weeks, at Contractor's option, after test results for three consecutive test periods are satisfactory.

Hydrostatic testing shall be performed in a dry, well-lighted area with ambient and test water temperatures above 35 °F. If test assembly is tested in horizontal orientation, test pressure shall be measured at the horizontal centerline of the pipe; if tested in vertical orientation, test pressure shall be measured at the top of the assembly. Test gauges and instruments used shall have been calibrated within 90 days of use, and the Contracting Officer reserves the right to require calibration whenever deemed necessary.

Pipe units for testing will be selected by an authorized representative of the Contracting Officer, and will be considered representative of the pipe produced during the test period. No repairs, corrections, or rework will be permitted on pipe units selected for testing. Testing shall be performed within 21 days after the end of the represented test period, and the Contracting Officer shall be given at least 48 hours advance notice for each hydrostatic test.

Hydrostatic test of two pipe units and a joint shall be made by fastening suitable bulkheads on each end of the assembly and filling and pressurizing the test section with water. Testing shall be to 100 percent of the specified internal pressure for the pipe class involved. Pipe units and joint shall withstand test pressure for not less than 20 minutes without cracking or leakage appearing on the exterior surface. Pipe may be soaked under reduced pressure prior to testing, but not for more than 48 hours. Moisture appearing in the form of damp spots or beads adhering to the surface will not be considered leakage. Slow forming beads resulting in minor dripping which seal and dry up upon retesting will be considered satisfactory. Pipe maybe soaked under reduced pressure prior to retesting, but not for more than 96 hours.

If a pipe unit fails, the Contractor shall test two other pipe units from the same test period selected by an authorized representative of the Contracting Officer. If both of these pipe units test successfully, the remainder of the pipe in that test period run will be approved. If either pipe unit fails, each remaining pipe in the test period run shall be tested.

h. Water. - Tests demonstrating conformance with these specifications for the water proposed for use.

TABLE 1. - DESIGN REQUIREMENTS FOR REINFORCED CONCRETE PRESSURE PIPE

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 12 | | 15 | | 18 | | | | 21 | | | |
| TYPE OF REINFORCEMENT | CIRCULAR | | CIRCULAR | | CIRCULAR | | ELLIPTICAL | | CIRCULAR | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 2.00 | 3.00 | 2.00 | 3.00 | 2.25 | 3.00 | 2.25 | 3.00 | 2.38 | 3.00 | 2.38 | 3.00 |
| LAYERS OF REINFORCEMENT | SINGLE | SINGLE | SINGLE | SINGLE | SINGLE | SINGLE | SINGLE | SINGLE | SINGLE | SINGLE | SINGLE | SINGLE |
| CLASS | | | | | | | | | | | | |
| A-25 | 0.08 | 0.07 | 0.11 | 0.09 | 0.14 | 0.12 | 0.13 | 0.12 | 0.18 | 0.16 | 0.16 | 0.14 |
| B-25 | 0.11 | 0.09 | 0.17 | 0.13 | 0.21 | 0.17 | 0.20 | 0.13 | 0.28 | 0.23 | 0.24 | 0.17 |
| C-25 | 0.15 | 0.11 | 0.23 | 0.16 | 0.30 | 0.23 | 0.27 | 0.17 | 0.39 | 0.31 | 0.34 | 0.23 |
| D-25 | 0.19 | 0.13 | 0.30 | 0.20 | 0.39 | 0.29 | 0.36 | 0.21 | 0.53 | 0.40 | 0.44 | 0.29 |
| A-50 | 0.11 | 0.11 | 0.16 | 0.14 | 0.19 | 0.18 | 0.25 | 0.25 | 0.24 | 0.22 | 0.29 | 0.29 |
| B-50 | 0.15 | 0.12 | 0.21 | 0.17 | 0.27 | 0.23 | 0.25 | 0.25 | 0.34 | 0.29 | 0.30 | 0.29 |
| C-50 | 0.18 | 0.14 | 0.27 | 0.21 | 0.35 | 0.28 | 0.32 | 0.25 | 0.45 | 0.37 | 0.39 | 0.29 |
| D-50 | 0.22 | 0.16 | 0.34 | 0.24 | 0.44 | 0.34 | 0.41 | 0.25 | | 0.46 | 0.50 | 0.33 |
| A-75 | 0.17 | 0.17 | 0.21 | 0.21 | 0.25 | 0.25 | | | 0.30 | 0.29 | | |
| B-75 | 0.18 | 0.17 | 0.26 | 0.21 | 0.32 | 0.28 | | | 0.40 | 0.35 | | |
| C-75 | 0.22 | 0.18 | 0.32 | 0.25 | 0.40 | 0.33 | | | 0.51 | 0.43 | | |
| D-75 | 0.26 | 0.20 | 0.39 | 0.29 | 0.50 | 0.39 | | | | 0.52 | | |
| A-100 | 0.24 | 0.24 | 0.29 | 0.29 | 0.35 | 0.35 | | | 0.41 | 0.41 | | |
| B-100 | 0.24 | 0.24 | 0.30 | 0.29 | 0.37 | 0.35 | | | 0.46 | 0.41 | | |
| C-100 | 0.25 | 0.24 | 0.36 | 0.29 | 0.45 | 0.39 | | | 0.57 | 0.49 | | |
| D-100 | 0.29 | 0.24 | 0.43 | 0.33 | 0.55 | 0.44 | | | | 0.58 | | |
| A-125 | 0.31 | 0.31 | 0.39 | 0.39 | 0.47 | 0.47 | | | 0.55 | 0.55 | | |
| B-125 | 0.31 | 0.31 | 0.39 | 0.39 | 0.47 | 0.47 | | | 0.55 | 0.55 | | |
| C-125 | 0.31 | 0.31 | 0.40 | 0.39 | 0.51 | 0.47 | | | 0.63 | 0.55 | | |
| D-125 | 0.33 | 0.31 | 0.47 | 0.39 | 0.60 | 0.50 | | | | 0.64 | | |
| A-150 | 0.40 | 0.40 | 0.50 | 0.50 | 0.60 | 0.60 | | | 0.70 | 0.70 | | |
| B-150 | 0.40 | 0.40 | 0.50 | 0.50 | 0.60 | 0.60 | | | 0.70 | 0.70 | | |
| C-150 | 0.40 | 0.40 | 0.50 | 0.50 | 0.60 | 0.60 | | | 0.70 | 0.70 | | |
| D-150 | 0.40 | 0.40 | 0.52 | 0.50 | 0.66 | 0.60 | | | | 0.70 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 24 | | | | 27 | | | | | | | |
| TYPE OF REINFORCEMENT | CIRCULAR | | ELLIPTICAL | | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 2.50 | 3.00 | 2.50 | 3.00 | 2.62 | 3.12 | 3.25 | | 4.25 | | 2.62 | 3.25 |
| LAYERS OF REINFORCEMENT | SINGLE | SINGLE | SINGLE | SINGLE | SINGLE | SINGLE | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | | | | | |
| A- 25 | 0.21 | 0.19 | 0.18 | 0.16 | 0.25 | 0.23 | 0.16 | 0.10 | 0.13 | 0.07 | 0.20 | 0.18 |
| B- 25 | 0.34 | 0.29 | 0.29 | 0.22 | 0.42 | 0.36 | 0.25 | 0.13 | 0.18 | 0.09 | 0.33 | 0.25 |
| C- 25 | 0.50 | 0.40 | 0.40 | 0.29 | | 0.50 | 0.33 | 0.16 | 0.24 | 0.10 | 0.47 | 0.33 |
| D- 25 | | 0.53 | 0.54 | 0.38 | | 0.67 | 0.42 | 0.20 | 0.29 | 0.11 | 0.63 | 0.42 |
| A- 50 | 0.28 | 0.26 | 0.33 | 0.33 | 0.33 | 0.30 | 0.22 | 0.16 | 0.18 | 0.13 | 0.37 | 0.37 |
| B- 50 | 0.41 | 0.36 | 0.35 | 0.33 | 0.50 | 0.44 | 0.30 | 0.19 | 0.24 | 0.14 | 0.40 | 0.37 |
| C- 50 | 0.57 | 0.48 | 0.46 | 0.35 | | 0.58 | 0.38 | 0.22 | 0.29 | 0.15 | 0.53 | 0.38 |
| D- 50 | | 0.60 | 0.59 | 0.43 | | 0.75 | 0.47 | 0.25 | 0.34 | 0.16 | 0.69 | 0.47 |
| A- 75 | 0.35 | 0.33 | | | 0.41 | 0.38 | 0.28 | 0.21 | 0.23 | 0.18 | | |
| B- 75 | 0.48 | 0.43 | | | 0.58 | 0.52 | 0.36 | 0.24 | 0.29 | 0.19 | | |
| C- 75 | 0.64 | 0.55 | | | | 0.66 | 0.44 | 0.27 | 0.34 | 0.20 | | |
| D- 75 | | 0.67 | | | | | 0.53 | 0.31 | 0.39 | 0.21 | | |
| A-100 | 0.47 | 0.47 | | | 0.52 | 0.52 | 0.33 | 0.27 | 0.30 | 0.23 | | |
| B-100 | 0.55 | 0.50 | | | 0.66 | 0.59 | 0.42 | 0.30 | 0.34 | 0.24 | | |
| C-100 | 0.71 | 0.62 | | | | 0.74 | 0.50 | 0.33 | 0.39 | 0.25 | | |
| D-100 | | 0.74 | | | | | 0.58 | 0.36 | 0.44 | 0.27 | | |
| A-125 | 0.62 | 0.62 | | | 0.70 | 0.70 | 0.39 | 0.32 | 0.39 | 0.32 | | |
| B-125 | 0.62 | 0.62 | | | 0.74 | 0.70 | 0.47 | 0.36 | 0.40 | 0.30 | | |
| C-125 | 0.78 | 0.69 | | | | 0.82 | 0.55 | 0.39 | 0.44 | 0.30 | | |
| D-125 | | 0.81 | | | | | 0.64 | 0.42 | 0.49 | 0.32 | | |
| A-150 | 0.80 | 0.80 | | | 0.90 | 0.90 | 0.50 | 0.40 | 0.49 | 0.41 | | |
| B-150 | 0.80 | 0.80 | | | | 0.90 | 0.53 | 0.42 | 0.50 | 0.40 | | |
| C-150 | | 0.80 | | | | 0.90 | 0.61 | 0.44 | 0.52 | 0.38 | | |
| D-150 | | 0.88 | | | | | 0.69 | 0.47 | 0.54 | 0.37 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 30 | | | | | | | | | |
| TYPE OF REINFORCE-MENT | CIRCULAR | | | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 2.75 | 3.12 | 3.25 | | 3.50 | | 4.75 | | 2.75 | 3.50 |
| LAYERS OF REINFORCE-MENT | SINGLE | SINGLE | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | | | |
| A- 25 | 0.29 | 0.27 | 0.19 | 0.12 | 0.18 | 0.11 | 0.14 | 0.08 | 0.23 | 0.20 |
| B- 25 | 0.50 | 0.44 | 0.30 | 0.16 | 0.27 | 0.14 | 0.20 | 0.09 | 0.38 | 0.27 |
| C- 25 | | 0.64 | 0.41 | 0.21 | 0.37 | 0.18 | 0.26 | 0.11 | 0.54 | 0.37 |
| D- 25 | | | 0.53 | 0.26 | 0.47 | 0.22 | 0.31 | 0.12 | 0.74 | 0.47 |
| A- 50 | 0.38 | 0.36 | 0.25 | 0.18 | 0.24 | 0.17 | 0.20 | 0.14 | 0.41 | 0.41 |
| B- 50 | 0.59 | 0.53 | 0.36 | 0.22 | 0.33 | 0.20 | 0.25 | 0.15 | 0.45 | 0.41 |
| C- 50 | | 0.72 | 0.47 | 0.27 | 0.42 | 0.24 | 0.31 | 0.16 | 0.61 | 0.42 |
| D- 50 | | | 0.58 | 0.32 | 0.52 | 0.28 | 0.37 | 0.18 | | 0.52 |
| A- 75 | 0.47 | 0.44 | 0.32 | 0.24 | 0.30 | 0.23 | 0.25 | 0.19 | | |
| B- 75 | 0.68 | 0.62 | 0.42 | 0.29 | 0.39 | 0.27 | 0.31 | 0.20 | | |
| C- 75 | | 0.81 | 0.53 | 0.33 | 0.48 | 0.30 | 0.36 | 0.22 | | |
| D- 75 | | | 0.64 | 0.38 | 0.58 | 0.34 | 0.42 | 0.23 | | |
| A-100 | 0.58 | 0.58 | 0.38 | 0.31 | 0.36 | 0.29 | 0.33 | 0.26 | | |
| B-100 | 0.77 | 0.71 | 0.49 | 0.35 | 0.45 | 0.33 | 0.37 | 0.26 | | |
| C-100 | | 0.90 | 0.59 | 0.39 | 0.54 | 0.36 | 0.42 | 0.27 | | |
| D-100 | | | 0.70 | 0.44 | 0.64 | 0.40 | 0.47 | 0.28 | | |
| A-125 | 0.78 | 0.78 | 0.45 | 0.37 | 0.43 | 0.35 | 0.43 | 0.35 | | |
| B-125 | 0.85 | 0.79 | 0.55 | 0.41 | 0.52 | 0.39 | 0.44 | 0.34 | | |
| C-125 | | 0.99 | 0.65 | 0.45 | 0.60 | 0.42 | 0.47 | 0.33 | | |
| D-125 | | | 0.76 | 0.50 | 0.70 | 0.46 | 0.53 | 0.34 | | |
| A-150 | 1.00 | 1.00 | 0.55 | 0.45 | 0.55 | 0.45 | 0.55 | 0.45 | | |
| B-150 | | 1.00 | 0.61 | 0.48 | 0.58 | 0.45 | 0.57 | 0.44 | | |
| C-150 | | | 0.71 | 0.52 | 0.66 | 0.48 | 0.58 | 0.42 | | |
| D-150 | | | 0.82 | 0.56 | 0.76 | 0.52 | 0.60 | 0.41 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 33 | | | | | | | | | |
| TYPE OF REINFORCE-MENT | CIRCULAR | | | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 2.88 | 3.12 | 3.25 | | 3.75 | | 4.75 | | 2.88 | 3.75 |
| LAYERS OF REINFORCE-MENT | SINGLE | SINGLE | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | | | |
| A- 25 | 0.33 | 0.32 | 0.22 | 0.14 | 0.19 | 0.12 | 0.16 | 0.09 | 0.25 | 0.22 |
| B- 25 | 0.59 | 0.54 | 0.36 | 0.20 | 0.30 | 0.16 | 0.24 | 0.11 | 0.43 | 0.30 |
| C- 25 | | | 0.50 | 0.26 | 0.40 | 0.20 | 0.31 | 0.13 | 0.61 | 0.40 |
| D- 25 | | | 0.65 | 0.33 | 0.51 | 0.25 | 0.38 | 0.16 | | 0.51 |
| A- 50 | 0.43 | 0.41 | 0.29 | 0.21 | 0.26 | 0.18 | 0.22 | 0.16 | 0.46 | 0.46 |
| B- 50 | 0.69 | 0.64 | 0.43 | 0.27 | 0.37 | 0.22 | 0.30 | 0.18 | 0.50 | 0.46 |
| C- 50 | | | 0.56 | 0.32 | 0.47 | 0.26 | 0.36 | 0.19 | 0.68 | 0.47 |
| D- 50 | | | 0.71 | 0.39 | 0.57 | 0.31 | 0.44 | 0.22 | | 0.57 |
| A- 75 | 0.53 | 0.51 | 0.36 | 0.28 | 0.33 | 0.25 | 0.28 | 0.22 | | |
| B- 75 | 0.79 | 0.74 | 0.49 | 0.33 | 0.43 | 0.29 | 0.36 | 0.24 | | |
| C- 75 | | | 0.63 | 0.39 | 0.53 | 0.33 | 0.42 | 0.25 | | |
| D- 75 | | | 0.77 | 0.46 | 0.64 | 0.37 | 0.49 | 0.28 | | |
| A-100 | 0.64 | 0.64 | 0.43 | 0.35 | 0.39 | 0.32 | 0.36 | 0.29 | | |
| B-100 | 0.88 | 0.83 | 0.56 | 0.40 | 0.49 | 0.35 | 0.42 | 0.30 | | |
| C-100 | | | 0.69 | 0.46 | 0.59 | 0.39 | 0.48 | 0.32 | | |
| D-100 | | | 0.84 | 0.52 | 0.70 | 0.43 | 0.55 | 0.34 | | |
| A-125 | 0.85 | 0.85 | 0.50 | 0.42 | 0.48 | 0.38 | 0.48 | 0.38 | | |
| B-125 | 0.98 | 0.93 | 0.63 | 0.47 | 0.56 | 0.42 | 0.49 | 0.37 | | |
| C-125 | | | 0.76 | 0.53 | 0.66 | 0.46 | 0.54 | 0.38 | | |
| D-125 | | | 0.90 | 0.59 | 0.76 | 0.50 | 0.61 | 0.39 | | |
| A-150 | | 1.10 | 0.61 | 0.50 | 0.61 | 0.49 | 0.61 | 0.50 | | |
| B-150 | | | 0.70 | 0.54 | 0.63 | 0.49 | 0.62 | 0.48 | | |
| C-150 | | | 0.82 | 0.60 | 0.72 | 0.52 | 0.64 | 0.47 | | |
| D-150 | | | 0.96 | 0.66 | 0.82 | 0.56 | 0.67 | 0.46 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 36 | | | | | | | | |
| TYPE OF REINFORCEMENT | CIRCULAR | | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 3.12 | 3.25 | | 4.00 | | 5.00 | | 3.12 | 4.00 |
| LAYERS OF REINFORCEMENT | SINGLE | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | | |
| A- 25 | 0.37 | 0.26 | 0.16 | 0.21 | 0.13 | 0.19 | 0.11 | 0.27 | 0.24 |
| B- 25 | 0.66 | 0.43 | 0.24 | 0.33 | 0.17 | 0.28 | 0.14 | 0.45 | 0.33 |
| C- 25 | | 0.60 | 0.32 | 0.44 | 0.22 | 0.37 | 0.16 | 0.64 | 0.44 |
| D- 25 | | 0.79 | 0.41 | 0.56 | 0.27 | 0.46 | 0.19 | | 0.56 |
| A- 50 | 0.47 | 0.33 | 0.24 | 0.28 | 0.20 | 0.26 | 0.18 | 0.50 | 0.50 |
| B- 50 | 0.77 | 0.50 | 0.31 | 0.40 | 0.24 | 0.35 | 0.21 | 0.52 | 0.50 |
| C- 50 | | 0.66 | 0.39 | 0.51 | 0.29 | 0.43 | 0.23 | 0.71 | 0.51 |
| D- 50 | | 0.86 | 0.48 | 0.63 | 0.34 | 0.52 | 0.26 | | 0.63 |
| A- 75 | 0.58 | 0.41 | 0.31 | 0.35 | 0.27 | 0.33 | 0.25 | | |
| B- 75 | 0.87 | 0.57 | 0.39 | 0.47 | 0.31 | 0.42 | 0.28 | | |
| C- 75 | | 0.73 | 0.46 | 0.57 | 0.36 | 0.50 | 0.30 | | |
| D- 75 | | 0.92 | 0.55 | 0.69 | 0.40 | 0.59 | 0.33 | | |
| A-100 | 0.70 | 0.48 | 0.39 | 0.42 | 0.34 | 0.40 | 0.31 | | |
| B-100 | 0.98 | 0.65 | 0.46 | 0.54 | 0.38 | 0.49 | 0.35 | | |
| C-100 | | 0.80 | 0.53 | 0.64 | 0.42 | 0.57 | 0.37 | | |
| D-100 | | 0.99 | 0.62 | 0.75 | 0.47 | 0.66 | 0.40 | | |
| A-125 | 0.93 | 0.56 | 0.47 | 0.52 | 0.42 | 0.52 | 0.41 | | |
| B-125 | | 0.72 | 0.54 | 0.60 | 0.45 | 0.56 | 0.42 | | |
| C-125 | | 0.88 | 0.61 | 0.71 | 0.49 | 0.64 | 0.44 | | |
| D-125 | | 1.05 | 0.69 | 0.82 | 0.54 | 0.72 | 0.47 | | |
| A-150 | | 0.66 | 0.55 | 0.67 | 0.54 | 0.67 | 0.54 | | |
| B-150 | | 0.79 | 0.61 | 0.68 | 0.53 | 0.68 | 0.53 | | |
| C-150 | | 0.95 | 0.68 | 0.78 | 0.56 | 0.71 | 0.51 | | |
| D-150 | | 1.12 | 0.76 | 0.89 | 0.61 | 0.79 | 0.53 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 39 | | | | | | | |
| TYPE OF REINFORCE-MENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 3.50 | | 4.25 | | 5.25 | | 3.50 | 4.25 |
| LAYERS OF REINFORCE-MENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A- 25 | 0.27 | 0.17 | 0.23 | 0.14 | 0.21 | 0.12 | 0.27 | 0.26 |
| B- 25 | 0.45 | 0.25 | 0.36 | 0.19 | 0.31 | 0.15 | 0.45 | 0.36 |
| C- 25 | 0.63 | 0.33 | 0.48 | 0.24 | 0.40 | 0.18 | 0.63 | 0.48 |
| D- 25 | 0.83 | 0.43 | 0.61 | 0.30 | 0.50 | 0.22 | | 0.61 |
| A- 50 | 0.35 | 0.25 | 0.30 | 0.21 | 0.28 | 0.20 | 0.54 | 0.54 |
| B- 50 | 0.53 | 0.33 | 0.43 | 0.26 | 0.38 | 0.23 | 0.54 | 0.54 |
| C- 50 | 0.70 | 0.41 | 0.55 | 0.31 | 0.48 | 0.26 | 0.70 | 0.55 |
| D- 50 | 0.90 | 0.50 | 0.68 | 0.37 | 0.57 | 0.29 | | 0.68 |
| A- 75 | 0.43 | 0.33 | 0.38 | 0.29 | 0.36 | 0.27 | | |
| B- 75 | 0.60 | 0.41 | 0.50 | 0.34 | 0.46 | 0.30 | | |
| C- 75 | 0.77 | 0.48 | 0.62 | 0.38 | 0.55 | 0.33 | | |
| D- 75 | 0.97 | 0.57 | 0.75 | 0.44 | 0.64 | 0.36 | | |
| A-100 | 0.51 | 0.41 | 0.45 | 0.36 | 0.43 | 0.34 | | |
| B-100 | 0.68 | 0.49 | 0.58 | 0.41 | 0.53 | 0.38 | | |
| C-100 | 0.85 | 0.56 | 0.69 | 0.46 | 0.62 | 0.40 | | |
| D-100 | 1.03 | 0.65 | 0.81 | 0.51 | 0.71 | 0.43 | | |
| A-125 | 0.59 | 0.49 | 0.57 | 0.44 | 0.57 | 0.44 | | |
| B-125 | 0.76 | 0.56 | 0.65 | 0.49 | 0.60 | 0.45 | | |
| C-125 | 0.92 | 0.64 | 0.76 | 0.53 | 0.69 | 0.48 | | |
| D-125 | 1.10 | 0.72 | 0.88 | 0.58 | 0.79 | 0.51 | | |
| A-150 | 0.72 | 0.59 | 0.73 | 0.58 | 0.72 | 0.58 | | |
| B-150 | 0.84 | 0.64 | 0.73 | 0.57 | 0.73 | 0.57 | | |
| C-150 | 0.99 | 0.72 | 0.83 | 0.60 | 0.77 | 0.55 | | |
| D-150 | 1.17 | 0.80 | 0.95 | 0.65 | 0.86 | 0.58 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 42 | | | | | | | |
| TYPE OF REINFORCE-MENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 3.75 | | 4.50 | | 5.50 | | 3.75 | 4.50 |
| LAYERS OF REINFORCE-MENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A- 25 | 0.29 | 0.18 | 0.25 | 0.15 | 0.23 | 0.13 | 0.29 | 0.28 |
| B- 25 | 0.48 | 0.26 | 0.38 | 0.20 | 0.33 | 0.17 | 0.48 | 0.38 |
| C- 25 | 0.66 | 0.35 | 0.52 | 0.26 | 0.44 | 0.20 | 0.66 | 0.52 |
| D- 25 | 0.87 | 0.45 | 0.66 | 0.32 | 0.55 | 0.24 | | 0.66 |
| A- 50 | 0.37 | 0.26 | 0.33 | 0.23 | 0.31 | 0.21 | 0.58 | 0.58 |
| B- 50 | 0.55 | 0.35 | 0.46 | 0.28 | 0.41 | 0.24 | 0.58 | 0.58 |
| C- 50 | 0.74 | 0.43 | 0.59 | 0.34 | 0.52 | 0.28 | 0.74 | 0.59 |
| D- 50 | 0.94 | 0.53 | 0.73 | 0.40 | 0.62 | 0.32 | | 0.73 |
| A- 75 | 0.46 | 0.35 | 0.40 | 0.31 | 0.39 | 0.29 | | |
| B- 75 | 0.63 | 0.43 | 0.54 | 0.36 | 0.49 | 0.32 | | |
| C- 75 | 0.81 | 0.51 | 0.67 | 0.41 | 0.59 | 0.36 | | |
| D- 75 | 1.01 | 0.60 | 0.80 | 0.47 | 0.70 | 0.39 | | |
| A-100 | 0.54 | 0.43 | 0.48 | 0.38 | 0.47 | 0.36 | | |
| B-100 | 0.71 | 0.51 | 0.61 | 0.44 | 0.57 | 0.40 | | |
| C-100 | 0.89 | 0.59 | 0.74 | 0.49 | 0.67 | 0.44 | | |
| D-100 | 1.08 | 0.68 | 0.87 | 0.54 | 0.77 | 0.47 | | |
| A-125 | 0.62 | 0.51 | 0.61 | 0.48 | 0.61 | 0.48 | | |
| B-125 | 0.80 | 0.59 | 0.69 | 0.52 | 0.65 | 0.48 | | |
| C-125 | 0.97 | 0.67 | 0.82 | 0.57 | 0.75 | 0.51 | | |
| D-125 | 1.16 | 0.76 | 0.95 | 0.62 | 0.85 | 0.55 | | |
| A-150 | 0.78 | 0.63 | 0.78 | 0.63 | 0.78 | 0.62 | | |
| B-150 | 0.88 | 0.68 | 0.79 | 0.62 | 0.79 | 0.61 | | |
| C-150 | 1.05 | 0.75 | 0.89 | 0.64 | 0.83 | 0.59 | | |
| D-150 | 1.23 | 0.84 | 1.02 | 0.70 | 0.93 | 0.63 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 45 | | | | | | | |
| TYPE OF REINFORCE-MENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 3.88 | | 4.75 | | 5.75 | | 3.88 | 4.75 |
| LAYERS OF REINFORCE-MENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A-25 | 0.32 | 0.19 | 0.27 | 0.16 | 0.25 | 0.14 | 0.32 | 0.30 |
| B-25 | 0.52 | 0.29 | 0.41 | 0.22 | 0.36 | 0.18 | 0.52 | 0.41 |
| C-25 | 0.73 | 0.39 | 0.56 | 0.28 | 0.48 | 0.22 | 0.73 | 0.56 |
| D-25 | 0.97 | 0.51 | 0.71 | 0.35 | 0.60 | 0.27 | | 0.71 |
| A-50 | 0.40 | 0.28 | 0.35 | 0.24 | 0.33 | 0.23 | 0.62 | 0.62 |
| B-50 | 0.60 | 0.37 | 0.49 | 0.30 | 0.44 | 0.26 | 0.62 | 0.62 |
| C-50 | 0.81 | 0.47 | 0.64 | 0.36 | 0.56 | 0.30 | 0.81 | 0.64 |
| D-50 | 1.04 | 0.58 | 0.78 | 0.43 | 0.68 | 0.35 | | 0.78 |
| A-75 | 0.49 | 0.37 | 0.43 | 0.33 | 0.41 | 0.31 | | |
| B-75 | 0.68 | 0.46 | 0.57 | 0.38 | 0.52 | 0.35 | | |
| C-75 | 0.89 | 0.56 | 0.71 | 0.44 | 0.64 | 0.39 | | |
| D-75 | 1.11 | 0.66 | 0.86 | 0.50 | 0.76 | 0.43 | | |
| A-100 | 0.58 | 0.46 | 0.52 | 0.40 | 0.50 | 0.38 | | |
| B-100 | 0.77 | 0.55 | 0.65 | 0.46 | 0.61 | 0.43 | | |
| C-100 | 0.97 | 0.64 | 0.79 | 0.52 | 0.72 | 0.47 | | |
| D-100 | 1.19 | 0.74 | 0.93 | 0.58 | 0.83 | 0.51 | | |
| A-125 | 0.67 | 0.54 | 0.65 | 0.51 | 0.65 | 0.52 | | |
| B-125 | 0.85 | 0.63 | 0.73 | 0.55 | 0.69 | 0.51 | | |
| C-125 | 1.05 | 0.73 | 0.87 | 0.60 | 0.80 | 0.55 | | |
| D-125 | 1.26 | 0.82 | 1.01 | 0.66 | 0.91 | 0.59 | | |
| A-150 | 0.83 | 0.67 | 0.83 | 0.67 | 0.83 | 0.67 | | |
| B-150 | 0.94 | 0.72 | 0.85 | 0.66 | 0.84 | 0.66 | | |
| C-150 | 1.13 | 0.81 | 0.95 | 0.68 | 0.89 | 0.63 | | |
| D-150 | 1.34 | 0.91 | 1.09 | 0.74 | 0.99 | 0.67 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 48 | | | | | | | |
| TYPE OF REINFORCEMENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 4.12 | | 5.00 | | 5.75 | | 4.12 | 5.00 |
| LAYERS OF REINFORCEMENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A- 25 | 0.33 | 0.20 | 0.31 | 0.18 | 0.27 | 0.16 | 0.33 | 0.31 |
| B- 25 | 0.54 | 0.30 | 0.47 | 0.25 | 0.40 | 0.21 | 0.54 | 0.47 |
| C- 25 | 0.77 | 0.41 | 0.65 | 0.33 | 0.55 | 0.26 | 0.77 | 0.65 |
| D- 25 | 1.01 | 0.53 | 0.83 | 0.41 | 0.68 | 0.32 | | 0.83 |
| A- 50 | 0.42 | 0.30 | 0.40 | 0.27 | 0.36 | 0.25 | 0.66 | 0.66 |
| B- 50 | 0.62 | 0.39 | 0.56 | 0.34 | 0.49 | 0.29 | 0.66 | 0.66 |
| C- 50 | 0.85 | 0.50 | 0.73 | 0.42 | 0.63 | 0.35 | 0.85 | 0.73 |
| D- 50 | 1.08 | 0.61 | 0.91 | 0.49 | 0.76 | 0.40 | | 0.91 |
| A- 75 | 0.52 | 0.39 | 0.49 | 0.37 | 0.45 | 0.34 | | |
| B- 75 | 0.71 | 0.48 | 0.65 | 0.43 | 0.58 | 0.38 | | |
| C- 75 | 0.93 | 0.58 | 0.82 | 0.51 | 0.72 | 0.43 | | |
| D- 75 | 1.16 | 0.69 | 0.99 | 0.58 | 0.85 | 0.48 | | |
| A-100 | 0.61 | 0.48 | 0.59 | 0.46 | 0.54 | 0.42 | | |
| B-100 | 0.80 | 0.57 | 0.74 | 0.52 | 0.66 | 0.47 | | |
| C-100 | 1.01 | 0.67 | 0.91 | 0.60 | 0.80 | 0.52 | | |
| D-100 | 1.24 | 0.78 | 1.08 | 0.67 | 0.93 | 0.57 | | |
| A-125 | 0.70 | 0.56 | 0.69 | 0.55 | 0.70 | 0.55 | | |
| B-125 | 0.89 | 0.66 | 0.83 | 0.62 | 0.75 | 0.56 | | |
| C-125 | 1.10 | 0.76 | 1.00 | 0.69 | 0.89 | 0.61 | | |
| D-125 | 1.31 | 0.86 | 1.16 | 0.76 | 1.01 | 0.66 | | |
| A-150 | 0.90 | 0.71 | 0.89 | 0.71 | 0.89 | 0.71 | | |
| B-150 | 0.98 | 0.75 | 0.92 | 0.71 | 0.90 | 0.70 | | |
| C-150 | 1.18 | 0.85 | 1.09 | 0.78 | 0.97 | 0.70 | | |
| D-150 | 1.39 | 0.95 | 1.25 | 0.85 | 1.10 | 0.74 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 51 | | | | | | | |
| TYPE OF REINFORCEMENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 4.25 | | 5.25 | | 6.00 | | 4.25 | 5.25 |
| LAYERS OF REINFORCEMENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A- 25 | 0.36 | 0.22 | 0.33 | 0.19 | 0.29 | 0.17 | 0.36 | 0.33 |
| B- 25 | 0.58 | 0.32 | 0.49 | 0.26 | 0.43 | 0.22 | 0.58 | 0.49 |
| C- 25 | 0.84 | 0.45 | 0.69 | 0.35 | 0.59 | 0.28 | 0.84 | 0.69 |
| D- 25 | 1.11 | 0.58 | 0.88 | 0.43 | 0.73 | 0.34 | | 0.88 |
| A- 50 | 0.46 | 0.32 | 0.42 | 0.29 | 0.39 | 0.26 | 0.70 | 0.70 |
| B- 50 | 0.67 | 0.42 | 0.59 | 0.36 | 0.52 | 0.31 | 0.70 | 0.70 |
| C- 50 | 0.92 | 0.54 | 0.78 | 0.44 | 0.68 | 0.37 | 0.94 | 0.78 |
| D- 50 | 1.18 | 0.67 | 0.96 | 0.52 | 0.82 | 0.43 | | 0.96 |
| A- 75 | 0.55 | 0.42 | 0.52 | 0.39 | 0.48 | 0.36 | | |
| B- 75 | 0.76 | 0.51 | 0.68 | 0.45 | 0.61 | 0.41 | | |
| C- 75 | 1.01 | 0.63 | 0.87 | 0.53 | 0.76 | 0.46 | | |
| D- 75 | 1.26 | 0.75 | 1.05 | 0.61 | 0.91 | 0.52 | | |
| A-100 | 0.65 | 0.51 | 0.62 | 0.49 | 0.58 | 0.44 | | |
| B-100 | 0.85 | 0.61 | 0.77 | 0.55 | 0.70 | 0.50 | | |
| C-100 | 1.10 | 0.72 | 0.96 | 0.63 | 0.85 | 0.55 | | |
| D-100 | 1.34 | 0.84 | 1.14 | 0.70 | 0.99 | 0.61 | | |
| A-125 | 0.75 | 0.60 | 0.74 | 0.58 | 0.74 | 0.58 | | |
| B-125 | 0.95 | 0.70 | 0.87 | 0.65 | 0.80 | 0.59 | | |
| C-125 | 1.18 | 0.81 | 1.05 | 0.72 | 0.94 | 0.65 | | |
| D-125 | 1.42 | 0.93 | 1.23 | 0.80 | 1.08 | 0.70 | | |
| A-150 | 0.95 | 0.75 | 0.95 | 0.76 | 0.95 | 0.76 | | |
| B-150 | 1.04 | 0.80 | 0.97 | 0.75 | 0.96 | 0.74 | | |
| C-150 | 1.27 | 0.91 | 1.15 | 0.82 | 1.04 | 0.74 | | |
| D-150 | 1.50 | 1.02 | 1.31 | 0.89 | 1.17 | 0.79 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 54 | | | | | | | |
| TYPE OF REINFORCE-MENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 4.50 | | 5.50 | | 6.25 | | 4.50 | 5.50 |
| LAYERS OF REINFORCE-MENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A- 25 | 0.38 | 0.23 | 0.35 | 0.20 | 0.32 | 0.18 | 0.38 | 0.35 |
| B- 25 | 0.60 | 0.34 | 0.52 | 0.28 | 0.46 | 0.24 | 0.60 | 0.52 |
| C- 25 | 0.88 | 0.47 | 0.73 | 0.37 | 0.63 | 0.30 | 0.88 | 0.73 |
| D- 25 | 1.15 | 0.61 | 0.93 | 0.46 | 0.79 | 0.37 | | 0.93 |
| A- 50 | 0.48 | 0.33 | 0.45 | 0.31 | 0.41 | 0.28 | 0.74 | 0.74 |
| B- 50 | 0.70 | 0.43 | 0.62 | 0.38 | 0.55 | 0.33 | 0.74 | 0.74 |
| C- 50 | 0.96 | 0.56 | 0.82 | 0.47 | 0.72 | 0.40 | 1.00 | 0.82 |
| D- 50 | 1.23 | 0.69 | 1.02 | 0.55 | 0.87 | 0.46 | | 1.02 |
| A- 75 | 0.58 | 0.43 | 0.55 | 0.41 | 0.51 | 0.38 | | |
| B- 75 | 0.79 | 0.53 | 0.71 | 0.48 | 0.65 | 0.43 | | |
| C- 75 | 1.05 | 0.66 | 0.92 | 0.56 | 0.81 | 0.49 | | |
| D- 75 | 1.31 | 0.78 | 1.11 | 0.65 | 0.96 | 0.55 | | |
| A-100 | 0.68 | 0.54 | 0.65 | 0.51 | 0.61 | 0.47 | | |
| B-100 | 0.89 | 0.63 | 0.81 | 0.58 | 0.74 | 0.53 | | |
| C-100 | 1.14 | 0.75 | 1.01 | 0.66 | 0.91 | 0.59 | | |
| D-100 | 1.39 | 0.87 | 1.20 | 0.74 | 1.06 | 0.65 | | |
| A-125 | 0.78 | 0.62 | 0.78 | 0.62 | 0.78 | 0.62 | | |
| B-125 | 0.98 | 0.73 | 0.91 | 0.68 | 0.84 | 0.63 | | |
| C-125 | 1.23 | 0.85 | 1.11 | 0.76 | 1.00 | 0.68 | | |
| D-125 | 1.48 | 0.96 | 1.29 | 0.84 | 1.15 | 0.74 | | |
| A-150 | 1.00 | 0.80 | 1.00 | 0.80 | 1.00 | 0.81 | | |
| B-150 | 1.08 | 0.83 | 1.02 | 0.79 | 1.02 | 0.78 | | |
| C-150 | 1.33 | 0.95 | 1.21 | 0.86 | 1.10 | 0.78 | | |
| D-150 | 1.56 | 1.06 | 1.38 | 0.94 | 1.24 | 0.84 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 57 | | | | | | | |
| TYPE OF REINFORCEMENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 4.75 | | 5.75 | | 6.50 | | 4.75 | 5.75 |
| LAYERS OF REINFORCEMENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A- 25 | 0.40 | 0.24 | 0.37 | 0.22 | 0.34 | 0.19 | 0.40 | 0.37 |
| B- 25 | 0.62 | 0.35 | 0.54 | 0.29 | 0.48 | 0.25 | 0.62 | 0.54 |
| C- 25 | 0.92 | 0.49 | 0.77 | 0.39 | 0.67 | 0.33 | 0.92 | 0.77 |
| D- 25 | 1.20 | 0.63 | 0.98 | 0.49 | 0.84 | 0.40 | | 0.98 |
| A- 50 | 0.50 | 0.35 | 0.47 | 0.32 | 0.44 | 0.30 | 0.78 | 0.78 |
| B- 50 | 0.72 | 0.45 | 0.65 | 0.40 | 0.58 | 0.35 | 0.78 | 0.78 |
| C- 50 | 1.01 | 0.59 | 0.87 | 0.49 | 0.77 | 0.42 | 1.07 | 0.87 |
| D- 50 | 1.28 | 0.72 | 1.07 | 0.58 | 0.93 | 0.49 | | 1.07 |
| A- 75 | 0.61 | 0.45 | 0.58 | 0.43 | 0.54 | 0.40 | | |
| B- 75 | 0.82 | 0.55 | 0.75 | 0.50 | 0.68 | 0.45 | | |
| C- 75 | 1.10 | 0.69 | 0.97 | 0.59 | 0.86 | 0.52 | | |
| D- 75 | 1.36 | 0.81 | 1.17 | 0.68 | 1.02 | 0.59 | | |
| A-100 | 0.71 | 0.56 | 0.69 | 0.53 | 0.65 | 0.49 | | |
| B-100 | 0.92 | 0.66 | 0.85 | 0.60 | 0.78 | 0.55 | | |
| C-100 | 1.19 | 0.78 | 1.07 | 0.70 | 0.96 | 0.62 | | |
| D-100 | 1.45 | 0.91 | 1.26 | 0.78 | 1.12 | 0.69 | | |
| A-125 | 0.82 | 0.65 | 0.83 | 0.65 | 0.83 | 0.65 | | |
| B-125 | 1.02 | 0.76 | 0.96 | 0.71 | 0.89 | 0.66 | | |
| C-125 | 1.29 | 0.88 | 1.17 | 0.80 | 1.06 | 0.72 | | |
| D-125 | 1.54 | 1.00 | 1.36 | 0.88 | 1.21 | 0.78 | | |
| A-150 | 1.06 | 0.84 | 1.06 | 0.84 | 1.06 | 0.84 | | |
| B-150 | 1.13 | 0.87 | 1.07 | 0.83 | 1.08 | 0.83 | | |
| C-150 | 1.38 | 0.98 | 1.27 | 0.90 | 1.16 | 0.82 | | |
| D-150 | 1.63 | 1.10 | 1.45 | 0.98 | 1.31 | 0.88 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 60 | | | | | | | |
| TYPE OF REINFORCE-MENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 5.00 | | 6.00 | | 6.75 | | 5.00 | 6.00 |
| LAYERS OF REINFORCE-MENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A- 25 | 0.45 | 0.27 | 0.39 | 0.23 | 0.36 | 0.21 | 0.45 | 0.39 |
| B- 25 | 0.70 | 0.39 | 0.57 | 0.31 | 0.51 | 0.27 | 0.70 | 0.57 |
| C- 25 | 1.04 | 0.56 | 0.82 | 0.42 | 0.71 | 0.35 | 1.04 | 0.82 |
| D- 25 | 1.37 | 0.72 | 1.04 | 0.52 | 0.89 | 0.42 | | 1.04 |
| A- 50 | 0.57 | 0.39 | 0.50 | 0.34 | 0.47 | 0.31 | 0.82 | 0.82 |
| B- 50 | 0.81 | 0.50 | 0.68 | 0.41 | 0.62 | 0.37 | 0.82 | 0.82 |
| C- 50 | 1.14 | 0.66 | 0.92 | 0.52 | 0.81 | 0.45 | 1.14 | 0.92 |
| D- 50 | 1.46 | 0.82 | 1.13 | 0.62 | 0.99 | 0.52 | | 1.13 |
| A- 75 | 0.68 | 0.50 | 0.61 | 0.45 | 0.57 | 0.42 | | |
| B- 75 | 0.92 | 0.62 | 0.78 | 0.52 | 0.72 | 0.48 | | |
| C- 75 | 1.24 | 0.77 | 1.02 | 0.62 | 0.91 | 0.55 | | |
| D- 75 | 1.55 | 0.92 | 1.23 | 0.72 | 1.08 | 0.62 | | |
| A-100 | 0.80 | 0.62 | 0.72 | 0.56 | 0.68 | 0.52 | | |
| B-100 | 1.03 | 0.73 | 0.89 | 0.63 | 0.82 | 0.58 | | |
| C-100 | 1.34 | 0.88 | 1.12 | 0.73 | 1.01 | 0.66 | | |
| D-100 | 1.65 | 1.02 | 1.32 | 0.82 | 1.18 | 0.72 | | |
| A-125 | 0.92 | 0.73 | 0.88 | 0.68 | 0.87 | 0.68 | | |
| B-125 | 1.14 | 0.84 | 1.00 | 0.74 | 0.93 | 0.69 | | |
| C-125 | 1.45 | 0.99 | 1.22 | 0.84 | 1.12 | 0.76 | | |
| D-125 | 1.74 | 1.13 | 1.42 | 0.92 | 1.28 | 0.83 | | |
| A-150 | 1.11 | 0.89 | 1.12 | 0.88 | 1.12 | 0.89 | | |
| B-150 | 1.26 | 0.96 | 1.13 | 0.87 | 1.13 | 0.87 | | |
| C-150 | 1.56 | 1.10 | 1.33 | 0.94 | 1.22 | 0.87 | | |
| D-150 | 1.84 | 1.23 | 1.52 | 1.03 | 1.38 | 0.93 | | |

TABLE 1. - CONTINUED

| | MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 63 | | | | | | | |
| TYPE OF REINFORCEMENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 5.25 | | 6.25 | | 7.00 | | 5.25 | 6.25 |
| LAYERS OF REINFORCEMENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A- 25 | 0.47 | 0.28 | 0.41 | 0.24 | 0.41 | 0.23 | 0.47 | 0.41 |
| B- 25 | 0.72 | 0.40 | 0.60 | 0.32 | 0.58 | 0.30 | 0.72 | 0.60 |
| C- 25 | 1.07 | 0.57 | 0.85 | 0.43 | 0.80 | 0.39 | 1.07 | 0.85 |
| D- 25 | 1.42 | 0.74 | 1.09 | 0.54 | 1.02 | 0.48 | | 1.09 |
| A- 50 | 0.59 | 0.40 | 0.53 | 0.35 | 0.53 | 0.35 | 0.86 | 0.86 |
| B- 50 | 0.84 | 0.52 | 0.71 | 0.43 | 0.69 | 0.42 | 0.86 | 0.86 |
| C- 50 | 1.18 | 0.68 | 0.95 | 0.54 | 0.91 | 0.51 | 1.19 | 0.95 |
| D- 50 | 1.51 | 0.84 | 1.19 | 0.65 | 1.13 | 0.60 | | 1.20 |
| A- 75 | 0.71 | 0.52 | 0.64 | 0.47 | 0.64 | 0.47 | | |
| B- 75 | 0.95 | 0.64 | 0.82 | 0.55 | 0.81 | 0.53 | | |
| C- 75 | 1.28 | 0.79 | 1.06 | 0.65 | 1.02 | 0.62 | | |
| D- 75 | 1.60 | 0.95 | 1.29 | 0.75 | 1.23 | 0.71 | | |
| A-100 | 0.83 | 0.64 | 0.75 | 0.58 | 0.76 | 0.59 | | |
| B-100 | 1.06 | 0.75 | 0.93 | 0.66 | 0.93 | 0.65 | | |
| C-100 | 1.39 | 0.91 | 1.17 | 0.76 | 1.14 | 0.73 | | |
| D-100 | 1.70 | 1.06 | 1.39 | 0.86 | 1.34 | 0.82 | | |
| A-125 | 0.95 | 0.76 | 0.92 | 0.71 | 0.92 | 0.71 | | |
| B-125 | 1.18 | 0.87 | 1.04 | 0.77 | 1.04 | 0.77 | | |
| C-125 | 1.49 | 1.02 | 1.27 | 0.87 | 1.25 | 0.85 | | |
| D-125 | 1.80 | 1.16 | 1.49 | 0.97 | 1.45 | 0.93 | | |
| A-150 | 1.17 | 0.93 | 1.18 | 0.92 | 1.18 | 0.92 | | |
| B-150 | 1.30 | 0.99 | 1.19 | 0.91 | 1.19 | 0.91 | | |
| C-150 | 1.60 | 1.13 | 1.38 | 0.98 | 1.36 | 0.97 | | |
| D-150 | 1.90 | 1.27 | 1.60 | 1.07 | 1.56 | 1.05 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 66 | | | | | | | |
| TYPE OF REINFORCEMENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 5.50 | | 6.50 | | 7.25 | | 5.50 | 6.50 |
| LAYERS OF REINFORCEMENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A-25 | 0.50 | 0.30 | 0.44 | 0.25 | 0.43 | 0.25 | 0.50 | 0.44 |
| B-25 | 0.75 | 0.42 | 0.63 | 0.34 | 0.61 | 0.32 | 0.75 | 0.63 |
| C-25 | 1.10 | 0.59 | 0.88 | 0.45 | 0.84 | 0.41 | 1.10 | 0.88 |
| D-25 | 1.47 | 0.77 | 1.14 | 0.57 | 1.08 | 0.51 | | 1.14 |
| A-50 | 0.62 | 0.42 | 0.55 | 0.37 | 0.55 | 0.37 | 0.91 | 0.91 |
| B-50 | 0.87 | 0.54 | 0.74 | 0.45 | 0.73 | 0.44 | 0.91 | 0.91 |
| C-50 | 1.21 | 0.70 | 0.99 | 0.56 | 0.95 | 0.53 | 1.24 | 1.00 |
| D-50 | 1.56 | 0.87 | 1.25 | 0.68 | 1.19 | 0.63 | | 1.28 |
| A-75 | 0.74 | 0.54 | 0.67 | 0.49 | 0.68 | 0.49 | | |
| B-75 | 0.98 | 0.66 | 0.86 | 0.57 | 0.85 | 0.56 | | |
| C-75 | 1.31 | 0.81 | 1.10 | 0.68 | 1.07 | 0.65 | | |
| D-75 | 1.66 | 0.98 | 1.35 | 0.79 | 1.30 | 0.74 | | |
| A-100 | 0.86 | 0.67 | 0.79 | 0.61 | 0.80 | 0.61 | | |
| B-100 | 1.10 | 0.78 | 0.97 | 0.69 | 0.97 | 0.68 | | |
| C-100 | 1.42 | 0.93 | 1.21 | 0.79 | 1.18 | 0.77 | | |
| D-100 | 1.76 | 1.09 | 1.45 | 0.90 | 1.41 | 0.86 | | |
| A-125 | 0.99 | 0.78 | 0.97 | 0.74 | 0.96 | 0.75 | | |
| B-125 | 1.22 | 0.90 | 1.09 | 0.81 | 1.09 | 0.80 | | |
| C-125 | 1.54 | 1.05 | 1.32 | 0.91 | 1.30 | 0.89 | | |
| D-125 | 1.86 | 1.20 | 1.56 | 1.01 | 1.52 | 0.98 | | |
| A-150 | 1.23 | 0.97 | 1.23 | 0.97 | 1.23 | 0.97 | | |
| B-150 | 1.34 | 1.03 | 1.24 | 0.96 | 1.24 | 0.96 | | |
| C-150 | 1.65 | 1.17 | 1.44 | 1.02 | 1.42 | 1.01 | | |
| D-150 | 1.96 | 1.32 | 1.67 | 1.12 | 1.64 | 1.09 | | |

TABLE 1. - CONTINUED

| | MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 69 | | | | | | | |
| TYPE OF REINFORCE- MENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 5.75 | | 6.75 | | 7.50 | | 5.75 | 6.75 |
| LAYERS OF REINFORCE- MENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A- 25 | 0.52 | 0.31 | 0.46 | 0.27 | 0.46 | 0.26 | 0.52 | 0.46 |
| B- 25 | 0.78 | 0.43 | 0.66 | 0.35 | 0.64 | 0.33 | 0.78 | 0.66 |
| C- 25 | 1.13 | 0.60 | 0.92 | 0.47 | 0.88 | 0.43 | 1.13 | 0.92 |
| D- 25 | 1.51 | 0.79 | 1.20 | 0.60 | 1.13 | 0.54 | | 1.20 |
| A- 50 | 0.64 | 0.43 | 0.58 | 0.39 | 0.58 | 0.39 | 0.95 | 0.95 |
| B- 50 | 0.90 | 0.55 | 0.78 | 0.47 | 0.76 | 0.46 | 0.95 | 0.95 |
| C- 50 | 1.24 | 0.72 | 1.03 | 0.59 | 0.99 | 0.55 | 1.30 | 1.05 |
| D- 50 | 1.61 | 0.90 | 1.30 | 0.71 | 1.25 | 0.66 | | 1.36 |
| A- 75 | 0.77 | 0.56 | 0.70 | 0.51 | 0.71 | 0.51 | | |
| B- 75 | 1.02 | 0.68 | 0.90 | 0.59 | 0.89 | 0.58 | | |
| C- 75 | 1.35 | 0.84 | 1.14 | 0.70 | 1.11 | 0.67 | | |
| D- 75 | 1.71 | 1.01 | 1.41 | 0.82 | 1.36 | 0.78 | | |
| A-100 | 0.90 | 0.69 | 0.83 | 0.63 | 0.84 | 0.64 | | |
| B-100 | 1.14 | 0.80 | 1.01 | 0.72 | 1.01 | 0.71 | | |
| C-100 | 1.46 | 0.96 | 1.26 | 0.82 | 1.23 | 0.80 | | |
| D-100 | 1.81 | 1.13 | 1.52 | 0.94 | 1.47 | 0.90 | | |
| A-125 | 1.03 | 0.81 | 1.01 | 0.78 | 1.01 | 0.77 | | |
| B-125 | 1.26 | 0.93 | 1.14 | 0.84 | 1.14 | 0.84 | | |
| C 125 | 1.58 | 1.08 | 1.37 | 0.94 | 1.35 | 0.92 | | |
| D-125 | 1.92 | 1.24 | 1.63 | 1.05 | 1.59 | 1.02 | | |
| A-150 | 1.29 | 1.01 | 1.29 | 1.01 | 1.29 | 1.01 | | |
| B-150 | 1.39 | 1.06 | 1.30 | 1.00 | 1.30 | 1.00 | | |
| C-150 | 1.70 | 1.20 | 1.49 | 1.06 | 1.48 | 1.05 | | |
| D-150 | 2.03 | 1.36 | 1.74 | 1.17 | 1.71 | 1.14 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 72 | | | | | | | |
| TYPE OF REINFORCEMENT | CIRCULAR | | | | | | ELLIPTICAL | |
| WALL THICKNESS, IN. | 6.00 | | 7.00 | | 7.75 | | 6.00 | 7.00 |
| LAYERS OF REINFORCEMENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | SINGLE | SINGLE |
| CLASS | | | | | | | | |
| A-25 | 0.54 | 0.32 | 0.52 | 0.30 | 0.48 | 0.27 | 0.54 | 0.52 |
| B-25 | 0.80 | 0.45 | 0.74 | 0.39 | 0.67 | 0.35 | 0.80 | 0.74 |
| C-25 | 1.16 | 0.62 | 1.03 | 0.53 | 0.91 | 0.45 | 1.16 | 1.03 |
| D-25 | 1.56 | 0.82 | 1.37 | 0.68 | 1.19 | 0.57 | | 1.37 |
| A-50 | 0.67 | 0.45 | 0.65 | 0.43 | 0.61 | 0.40 | 0.99 | 0.99 |
| B-50 | 0.93 | 0.57 | 0.87 | 0.53 | 0.80 | 0.48 | 0.99 | 0.99 |
| C-50 | 1.27 | 0.74 | 1.15 | 0.65 | 1.03 | 0.58 | 1.35 | 1.15 |
| D-50 | 1.66 | 0.93 | 1.48 | 0.80 | 1.31 | 0.69 | | 1.48 |
| A-75 | 0.80 | 0.58 | 0.79 | 0.57 | 0.74 | 0.54 | | |
| B-75 | 1.05 | 0.70 | 1.00 | 0.66 | 0.92 | 0.61 | | |
| C-75 | 1.39 | 0.86 | 1.28 | 0.78 | 1.16 | 0.70 | | |
| D-75 | 1.77 | 1.05 | 1.60 | 0.93 | 1.42 | 0.81 | | |
| A-100 | 0.93 | 0.72 | 0.92 | 0.71 | 0.87 | 0.67 | | |
| B-100 | 1.18 | 0.83 | 1.13 | 0.79 | 1.05 | 0.74 | | |
| C-100 | 1.50 | 0.98 | 1.40 | 0.91 | 1.28 | 0.83 | | |
| D-100 | 1.87 | 1.16 | 1.71 | 1.05 | 1.54 | 0.94 | | |
| A-125 | 1.07 | 0.83 | 1.06 | 0.82 | 1.06 | 0.81 | | |
| B-125 | 1.31 | 0.96 | 1.26 | 0.93 | 1.18 | 0.87 | | |
| C-125 | 1.62 | 1.11 | 1.53 | 1.04 | 1.41 | 0.96 | | |
| D-125 | 1.98 | 1.28 | 1.83 | 1.18 | 1.66 | 1.06 | | |
| A-150 | 1.35 | 1.05 | 1.35 | 1.05 | 1.35 | 1.05 | | |
| B-150 | 1.43 | 1.09 | 1.40 | 1.07 | 1.36 | 1.04 | | |
| C-150 | 1.74 | 1.24 | 1.66 | 1.18 | 1.53 | 1.09 | | |
| D-150 | 2.09 | 1.40 | 1.96 | 1.31 | 1.78 | 1.19 | | |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 78 | | | | | | 84 | | | | | |
| TYPE OF REINFORCEMENT | CIRCULAR | | | | | | CIRCULAR | | | | | |
| WALL THICKNESS, IN. | 6.50 | | 7.50 | | 8.25 | | 7.00 | | 8.00 | | 8.75 | |
| LAYERS OF REINFORCEMENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | INNER | OUTER | INNER | OUTER | INNER | OUTER |
| CLASS | | | | | | | | | | | | |
| A- 25 | 0.59 | 0.35 | 0.57 | 0.32 | 0.53 | 0.30 | 0.69 | 0.40 | 0.62 | 0.35 | 0.59 | 0.33 |
| B- 25 | 0.86 | 0.48 | 0.80 | 0.43 | 0.73 | 0.38 | 1.00 | 0.55 | 0.87 | 0.46 | 0.80 | 0.42 |
| C- 25 | 1.22 | 0.65 | 1.10 | 0.56 | 0.99 | 0.49 | 1.40 | 0.74 | 1.18 | 0.60 | 1.07 | 0.53 |
| D- 25 | 1.67 | 0.87 | 1.48 | 0.74 | 1.31 | 0.63 | 1.94 | 1.01 | 1.58 | 0.79 | 1.40 | 0.68 |
| A- 50 | 0.73 | 0.49 | 0.71 | 0.47 | 0.67 | 0.44 | 0.85 | 0.56 | 0.77 | 0.50 | 0.73 | 0.47 |
| B- 50 | 0.99 | 0.61 | 0.94 | 0.57 | 0.87 | 0.52 | 1.14 | 0.70 | 1.01 | 0.61 | 0.94 | 0.56 |
| C- 50 | 1.34 | 0.78 | 1.23 | 0.70 | 1.12 | 0.62 | 1.53 | 0.88 | 1.32 | 0.75 | 1.20 | 0.67 |
| D- 50 | 1.78 | 0.99 | 1.60 | 0.87 | 1.43 | 0.76 | 2.06 | 1.14 | 1.71 | 0.93 | 1.53 | 0.82 |
| A- 75 | 0.87 | 0.63 | 0.85 | 0.61 | 0.81 | 0.58 | 1.00 | 0.71 | 0.92 | 0.66 | 0.88 | 0.62 |
| B- 75 | 1.13 | 0.75 | 1.08 | 0.71 | 1.00 | 0.66 | 1.29 | 0.85 | 1.16 | 0.76 | 1.09 | 0.71 |
| C- 75 | 1.46 | 0.91 | 1.37 | 0.84 | 1.25 | 0.76 | 1.67 | 1.03 | 1.46 | 0.89 | 1.34 | 0.81 |
| D- 75 | 1.89 | 1.11 | 1.72 | 1.00 | 1.55 | 0.89 | 2.18 | 1.28 | 1.84 | 1.07 | 1.66 | 0.95 |
| A-100 | 1.01 | 0.77 | 1.00 | 0.76 | 0.95 | 0.72 | 1.16 | 0.87 | 1.08 | 0.81 | 1.03 | 0.77 |
| B-100 | 1.26 | 0.88 | 1.22 | 0.85 | 1.14 | 0.80 | 1.44 | 1.00 | 1.31 | 0.91 | 1.23 | 0.86 |
| C-100 | 1.59 | 1.04 | 1.50 | 0.97 | 1.38 | 0.89 | 1.81 | 1.18 | 1.60 | 1.04 | 1.48 | 0.96 |
| D-100 | 2.00 | 1.24 | 1.85 | 1.13 | 1.68 | 1.02 | 2.31 | 1.42 | 1.97 | 1.21 | 1.80 | 1.09 |
| A-125 | 1.15 | 0.89 | 1.14 | 0.88 | 1.14 | 0.87 | 1.31 | 1.03 | 1.23 | 0.94 | 1.23 | 0.94 |
| B-125 | 1.39 | 1.02 | 1.36 | 0.99 | 1.28 | 0.94 | 1.59 | 1.16 | 1.45 | 1.06 | 1.38 | 1.00 |
| C-125 | 1.72 | 1.17 | 1.63 | 1.11 | 1.52 | 1.03 | 1.95 | 1.33 | 1.74 | 1.18 | 1.63 | 1.10 |
| D-125 | 2.11 | 1.36 | 1.97 | 1.27 | 1.81 | 1.15 | 2.44 | 1.56 | 2.10 | 1.35 | 1.93 | 1.23 |
| A-150 | 1.46 | 1.14 | 1.47 | 1.13 | 1.46 | 1.14 | 1.57 | 1.23 | 1.58 | 1.22 | 1.58 | 1.22 |
| B-150 | 1.53 | 1.16 | 1.50 | 1.14 | 1.48 | 1.12 | 1.75 | 1.32 | 1.60 | 1.21 | 1.60 | 1.20 |
| C-150 | 1.84 | 1.31 | 1.77 | 1.25 | 1.65 | 1.17 | 2.10 | 1.48 | 1.88 | 1.33 | 1.77 | 1.25 |
| D-150 | 2.23 | 1.49 | 2.10 | 1.40 | 1.93 | 1.29 | 2.57 | 1.70 | 2.24 | 1.49 | 2.07 | 1.38 |

TABLE 1. - CONTINUED

| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 90 | | | | 96 | | | |
| TYPE OF REINFORCE-MENT | CIRCULAR | | | | CIRCULAR | | | |
| WALL THICKNESS, IN. | 7.50 | | 8.00 | | 8.00 | | 8.50 | |
| LAYERS OF REINFORCE-MENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | INNER | OUTER |
| CLASS | | | | | | | | |
| A- 25 | 0.75 | 0.43 | 0.71 | 0.40 | 0.81 | 0.46 | 0.77 | 0.43 |
| B- 25 | 1.06 | 0.58 | 0.99 | 0.53 | 1.13 | 0.61 | 1.06 | 0.57 |
| C- 25 | 1.47 | 0.78 | 1.35 | 0.70 | 1.54 | 0.81 | 1.43 | 0.75 |
| D- 25 | 2.01 | 1.04 | 1.82 | 0.93 | 2.08 | 1.08 | 1.91 | 0.97 |
| A- 50 | 0.91 | 0.59 | 0.87 | 0.56 | 0.97 | 0.63 | 0.94 | 0.60 |
| B- 50 | 1.21 | 0.74 | 1.14 | 0.69 | 1.29 | 0.78 | 1.22 | 0.73 |
| C- 50 | 1.61 | 0.93 | 1.50 | 0.86 | 1.69 | 0.97 | 1.58 | 0.90 |
| D- 50 | 2.13 | 1.18 | 1.95 | 1.07 | 2.22 | 1.23 | 2.04 | 1.12 |
| A- 75 | 1.07 | 0.76 | 1.03 | 0.73 | 1.14 | 0.80 | 1.10 | 0.77 |
| B- 75 | 1.37 | 0.90 | 1.30 | 0.85 | 1.45 | 0.95 | 1.38 | 0.90 |
| C- 75 | 1.75 | 1.08 | 1.64 | 1.01 | 1.84 | 1.13 | 1.74 | 1.06 |
| D- 75 | 2.26 | 1.33 | 2.08 | 1.22 | 2.35 | 1.38 | 2.18 | 1.28 |
| A-100 | 1.23 | 0.92 | 1.19 | 0.89 | 1.31 | 0.98 | 1.27 | 0.95 |
| B-100 | 1.53 | 1.06 | 1.46 | 1.01 | 1.61 | 1.12 | 1.55 | 1.07 |
| C-100 | 1.90 | 1.24 | 1.79 | 1.16 | 2.00 | 1.30 | 1.89 | 1.23 |
| D-100 | 2.40 | 1.47 | 2.22 | 1.36 | 2.49 | 1.53 | 2.33 | 1.43 |
| A-125 | 1.40 | 1.08 | 1.36 | 1.04 | 1.49 | 1.14 | 1.45 | 1.10 |
| B-125 | 1.68 | 1.22 | 1.61 | 1.17 | 1.78 | 1.29 | 1.71 | 1.24 |
| C-125 | 2.05 | 1.39 | 1.94 | 1.32 | 2.15 | 1.46 | 2.05 | 1.39 |
| D-125 | 2.53 | 1.62 | 2.36 | 1.51 | 2.63 | 1.69 | 2.47 | 1.59 |
| A-150 | 1.69 | 1.31 | 1.69 | 1.30 | 1.80 | 1.39 | 1.81 | 1.39 |
| B-150 | 1.85 | 1.39 | 1.77 | 1.34 | 1.95 | 1.46 | 1.88 | 1.41 |
| C-150 | 2.20 | 1.55 | 2.09 | 1.48 | 2.31 | 1.63 | 2.21 | 1.56 |
| D-150 | 2.67 | 1.77 | 2.50 | 1.66 | 2.78 | 1.85 | 2.62 | 1.75 |

TABLE 1. - CONTINUED

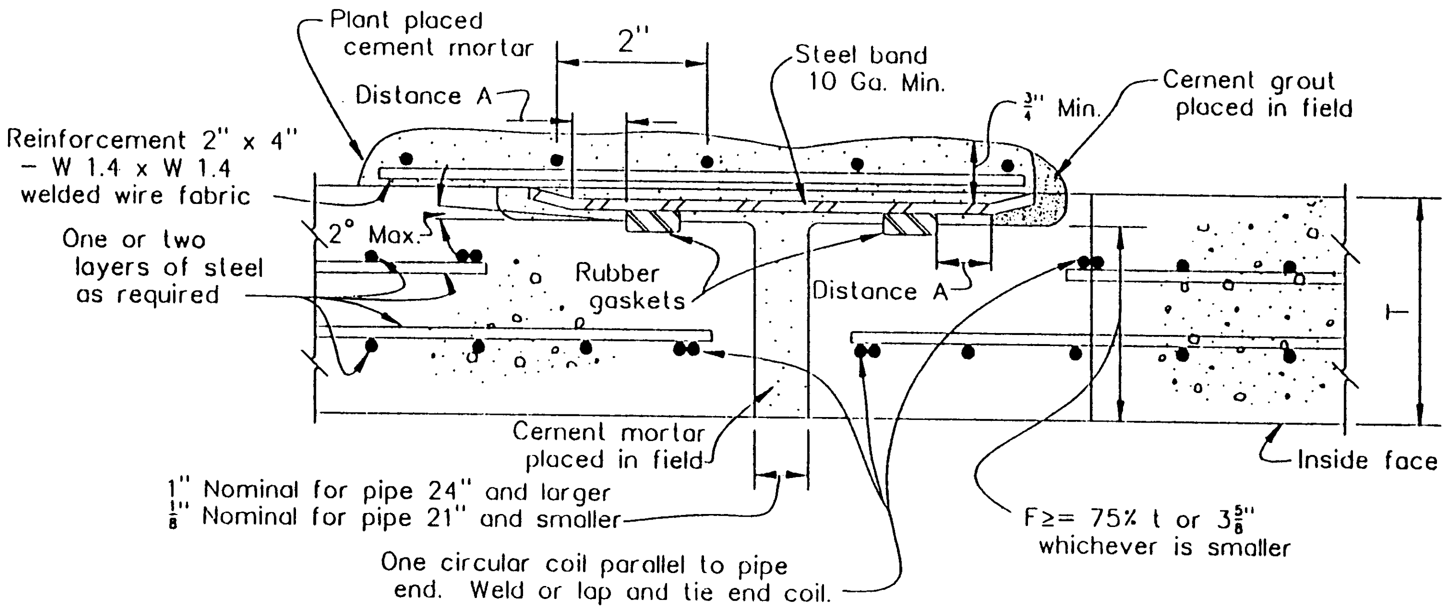
| MINIMUM CIRCUMFERENTIAL REINFORCEMENT IN SQUARE INCHES PER LINEAR FOOT OF PIPE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| INTERNAL DESIGNATED DIA., IN. | 102 | | | | 108 | | | |
| TYPE OF REINFORCE-MENT | CIRCULAR | | | | CIRCULAR | | | |
| WALL THICKNESS, IN. | 8.50 | | 9.00 | | 9.00 | | 9.50 | |
| LAYERS OF REINFORCE-MENT | INNER | OUTER | INNER | OUTER | INNER | OUTER | INNER | OUTER |
| CLASS | | | | | | | | |
| A- 25 | 0.87 | 0.49 | 0.83 | 0.46 | 0.93 | 0.52 | 0.90 | 0.50 |
| B- 25 | 1.20 | 0.65 | 1.13 | 0.61 | 1.27 | 0.69 | 1.21 | 0.64 |
| C- 25 | 1.62 | 0.85 | 1.52 | 0.79 | 1.70 | 0.90 | 1.60 | 0.83 |
| D- 25 | 2.17 | 1.12 | 2.00 | 1.02 | 2.26 | 1.17 | 2.09 | 1.07 |
| A- 50 | 1.04 | 0.67 | 1.01 | 0.64 | 1.11 | 0.71 | 1.08 | 0.68 |
| B- 50 | 1.37 | 0.82 | 1.30 | 0.78 | 1.45 | 0.87 | 1.38 | 0.82 |
| C- 50 | 1.78 | 1.02 | 1.67 | 0.95 | 1.87 | 1.07 | 1.77 | 1.00 |
| D- 50 | 2.31 | 1.28 | 2.14 | 1.18 | 2.40 | 1.33 | 2.24 | 1.23 |
| A- 75 | 1.22 | 0.85 | 1.18 | 0.82 | 1.30 | 0.90 | 1.26 | 0.87 |
| B- 75 | 1.54 | 1.00 | 1.47 | 0.95 | 1.62 | 1.05 | 1.56 | 1.01 |
| C- 75 | 1.94 | 1.19 | 1.83 | 1.12 | 2.03 | 1.25 | 1.93 | 1.18 |
| D- 75 | 2.45 | 1.44 | 2.29 | 1.34 | 2.55 | 1.50 | 2.40 | 1.40 |
| A-100 | 1.40 | 1.03 | 1.36 | 1.00 | 1.49 | 1.09 | 1.45 | 1.06 |
| B-100 | 1.71 | 1.18 | 1.64 | 1.13 | 1.80 | 1.24 | 1.74 | 1.19 |
| C-100 | 2.10 | 1.36 | 2.00 | 1.29 | 2.20 | 1.42 | 2.10 | 1.36 |
| D-100 | 2.59 | 1.60 | 2.44 | 1.50 | 2.70 | 1.66 | 2.56 | 1.57 |
| A-125 | 1.58 | 1.21 | 1.54 | 1.17 | 1.67 | 1.27 | 1.63 | 1.23 |
| B-125 | 1.88 | 1.36 | 1.82 | 1.31 | 1.99 | 1.42 | 1.92 | 1.38 |
| C-125 | 2.26 | 1.53 | 2.16 | 1.46 | 2.37 | 1.61 | 2.28 | 1.54 |
| D-125 | 2.75 | 1.76 | 2.59 | 1.66 | 2.86 | 1.84 | 2.72 | 1.74 |
| A-150 | 1.91 | 1.48 | 1.92 | 1.48 | 2.04 | 1.56 | 2.04 | 1.56 |
| B-150 | 2.06 | 1.54 | 1.99 | 1.49 | 2.17 | 1.61 | 2.11 | 1.57 |
| C-150 | 2.43 | 1.71 | 2.33 | 1.64 | 2.55 | 1.79 | 2.45 | 1.72 |
| D-150 | 2.90 | 1.93 | 2.75 | 1.83 | 3.02 | 2.01 | 2.88 | 1.92 |

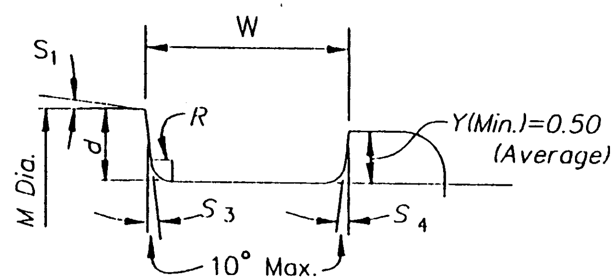
Table 2. - Minimum Bell Reinforcement

| | Minimum bell reinforcement in square inches to be distributed in 1-3/4 L | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Internal diameter of pipe in inches | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 48 | 51 | 54 |
| Class<br>A- 25<br>B- 25<br>C- 25<br>D- 25 | 0.11 | 0.13 | 0.15 | 0.17 | 0.19 | 0.23 | 0.25 | 0.27 | 0.29 | 0.31 | 0.33 | 0.35 | 0.38 | 0.40 | 0.42 |
| A- 50<br>B- 50<br>C- 50<br>D- 50 | 0.13 | 0.15 | 0.18 | 0.20 | 0.22 | 0.26 | 0.29 | 0.31 | 0.34 | 0.36 | 0.38 | 0.41 | 0.43 | 0.45 | 0.48 |
| A- 75<br>B- 75<br>C- 75<br>D- 75 | 0.15 | 0.17 | 0.20 | 0.23 | 0.25 | 0.30 | 0.33 | 0.36 | 0.39 | 0.41 | 0.44 | 0.47 | 0.49 | 0.52 | 0.55 |
| A-100<br>B-100<br>C-100<br>D-100 | 0.17 | 0.20 | 0.23 | 0.26 | 0.29 | 0.34 | 0.38 | 0.41 | 0.44 | 0.47 | 0.50 | 0.53 | 0.56 | 0.60 | 0.63 |
| A-125<br>B-125<br>C-125<br>D-125 | 0.19 | 0.23 | 0.26 | 0.30 | 0.33 | 0.39 | 0.43 | 0.47 | 0.50 | 0.54 | 0.57 | 0.61 | 0.65 | 0.68 | 0.72 |
| A-150<br>B-150<br>C-150<br>D-150 | 0.22 | 0.26 | 0.30 | 0.34 | 0.38 | 0.45 | 0.50 | 0.54 | 0.58 | 0.62 | 0.66 | 0.70 | 0.74 | 0.78 | 0.82 |

Table 2. - Minimum Bell Reinforcement - Continued

| | Minimum bell reinforcement in square inches to be distributed in 1-3/4 L | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Internal diameter of pipe in inches | 57 | 60 | 63 | 66 | 69 | 72 | 78 | 84 | 90 | 96 | 102 | 108 |
| Class<br>A- 25<br>B- 25<br>C- 25<br>D- 25 | 0.44 | 0.46 | 0.48 | 0.50 | 0.52 | 0.54 | 0.58 | 0.62 | 0.66 | 0.70 | 0.74 | 0.78 |
| A- 50<br>B- 50<br>C- 50<br>D- 50 | 0.50 | 0.52 | 0.55 | 0.57 | 0.59 | 0.62 | 0.66 | 0.71 | 0.76 | 0.81 | 0.85 | 0.90 |
| A- 75<br>B- 75<br>C- 75<br>D- 75 | 0.57 | 0.60 | 0.63 | 0.65 | 0.68 | 0.71 | 0.76 | 0.82 | 0.87 | 0.92 | 0.98 | 1.03 |
| A-100<br>B-100<br>C-100<br>D-100 | 0.66 | 0.69 | 0.72 | 0.75 | 0.78 | 0.81 | 0.87 | 0.93 | 0.99 | 1.05 | 1.12 | 1.18 |
| A-125<br>B-125<br>C-125<br>D-125 | 0.75 | 0.79 | 0.82 | 0.86 | 0.89 | 0.93 | 1.00 | 1.07 | 1.14 | 1.21 | 1.28 | 1.35 |
| A-150<br>B-150<br>C-150<br>D-150 | 0.86 | 0.90 | 0.94 | 0.98 | 1.02 | 1.06 | 1.14 | 1.22 | 1.30 | 1.38 | 1.46 | 1.54 |



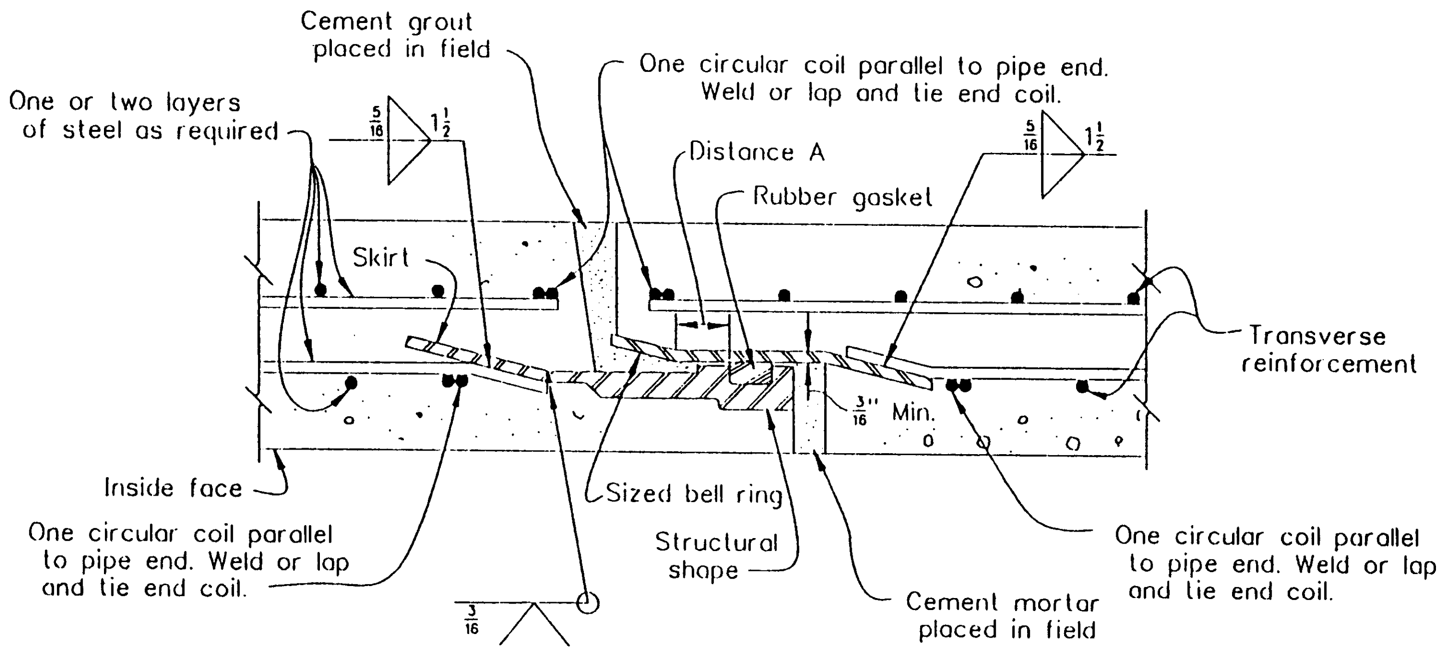

*SPIGOT GROOVE DETAIL*

NOTES

t = Minimum pipe wall thickness for size of pipe as given in Table 1.
T = Wall thickness of pipe furnished.

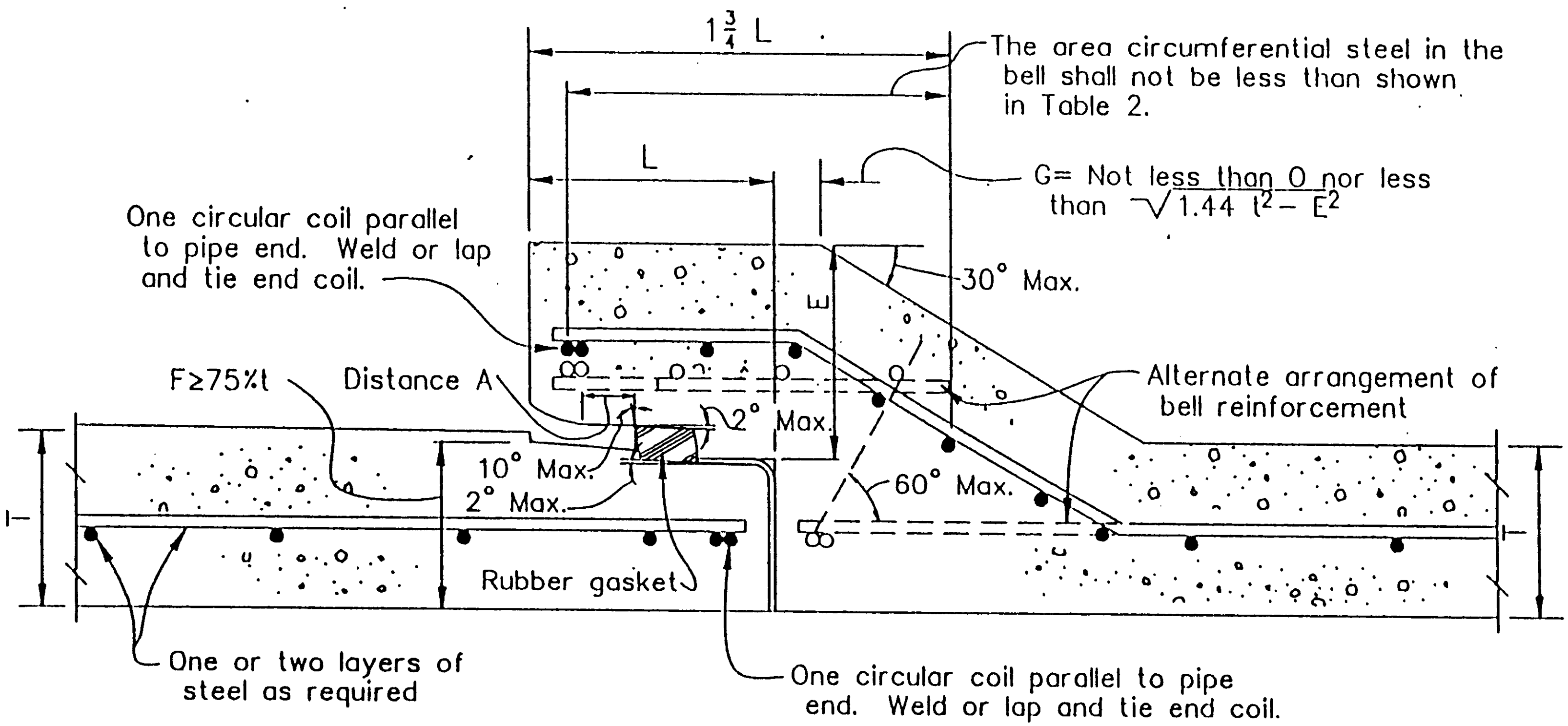
# JOINT TYPE R–1
## REINFORCED CONCRETE PRESSURE PIPE

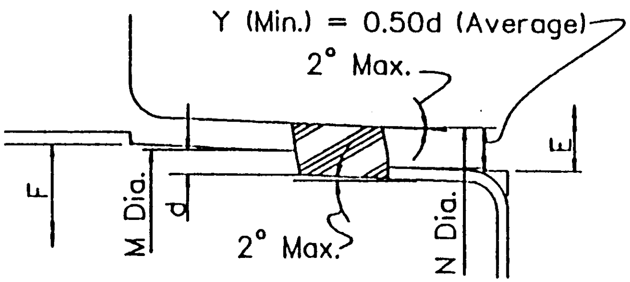
FIGURE 1




# JOINT TYPE R-2
## REINFORCED CONCRETE PRESSURE PIPE

FIGURE 2



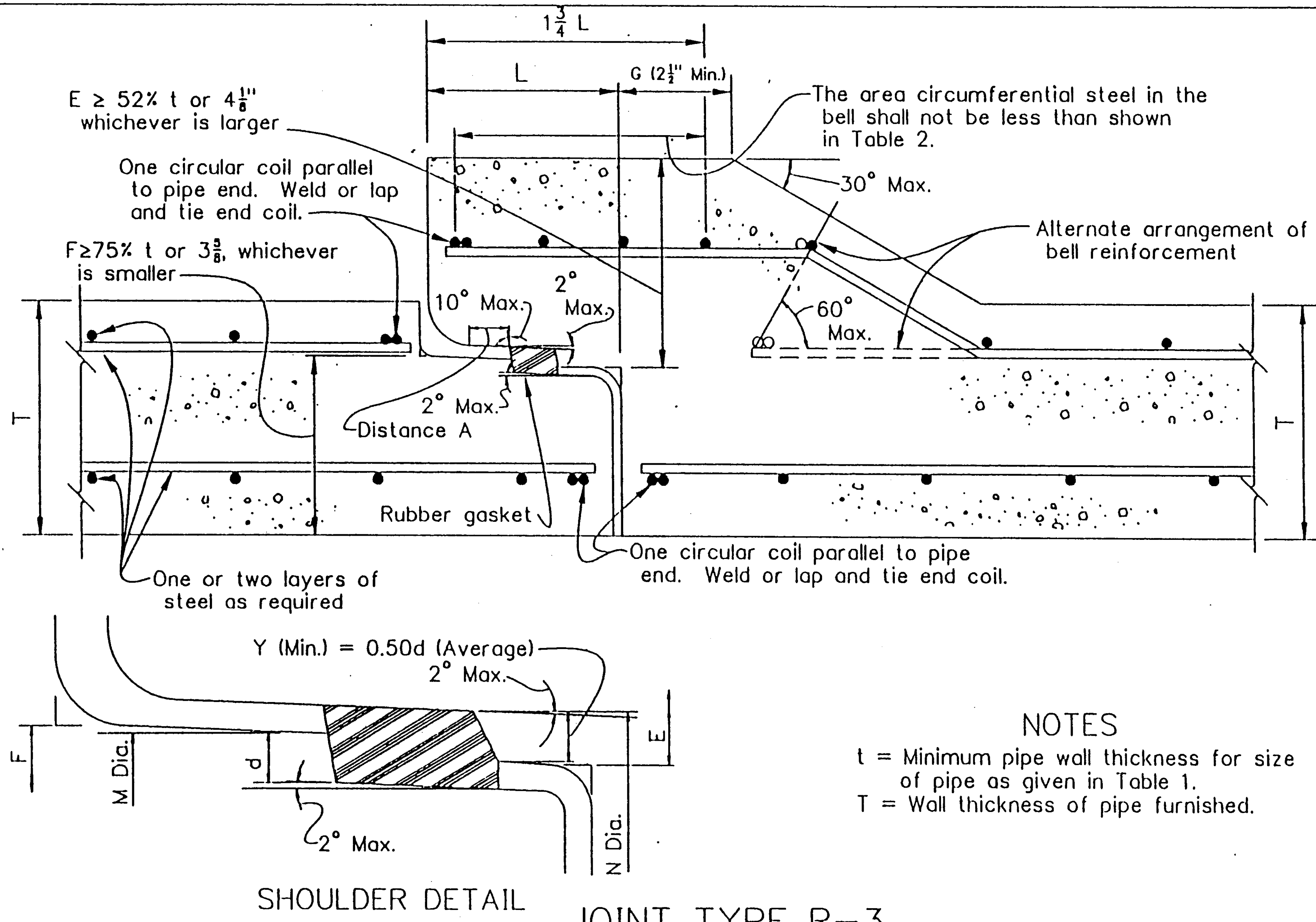

SHOULDER DETAIL

NOTES

t = Minimum pipe wall thickness for size of pipe as given in Table 1.
T = Wall thickness of pipe furnished.
E ≥ t or $4\frac{1}{8}$'' whichever is smaller.

# JOINT TYPE R-3

## REINFORCED CONCRETE PRESSURE PIPE (T= 2'' TO $4\frac{1}{2}$'' INCLUSIVE)

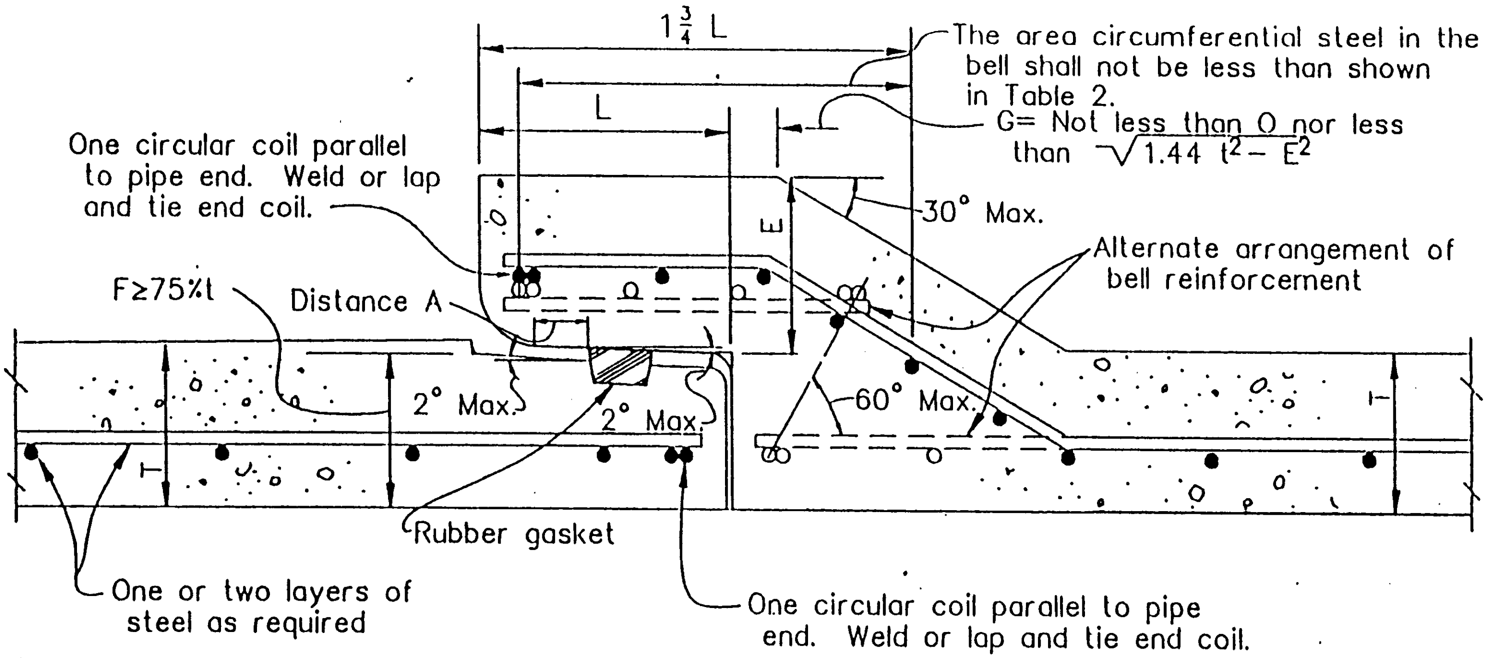


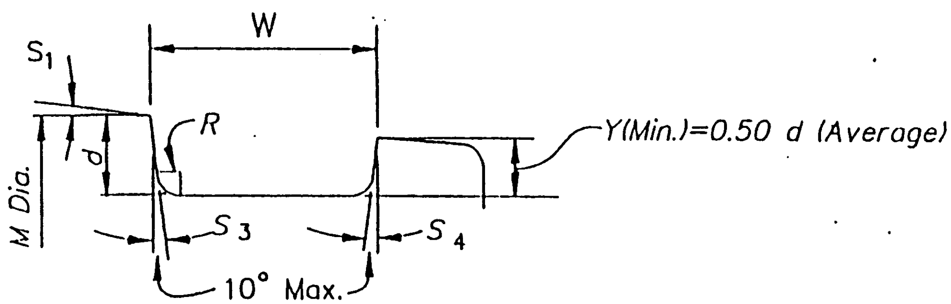

## NOTES

t = Minimum pipe wall thickness for size of pipe as given in Table 1.
T = Wall thickness of pipe furnished.

# JOINT TYPE R-3
## REINFORCED CONCRETE PRESSURE PIPE
## ( T = $4\frac{5}{8}$" and LARGER )

FIGURE




SPIGOT GROOVE DETAIL

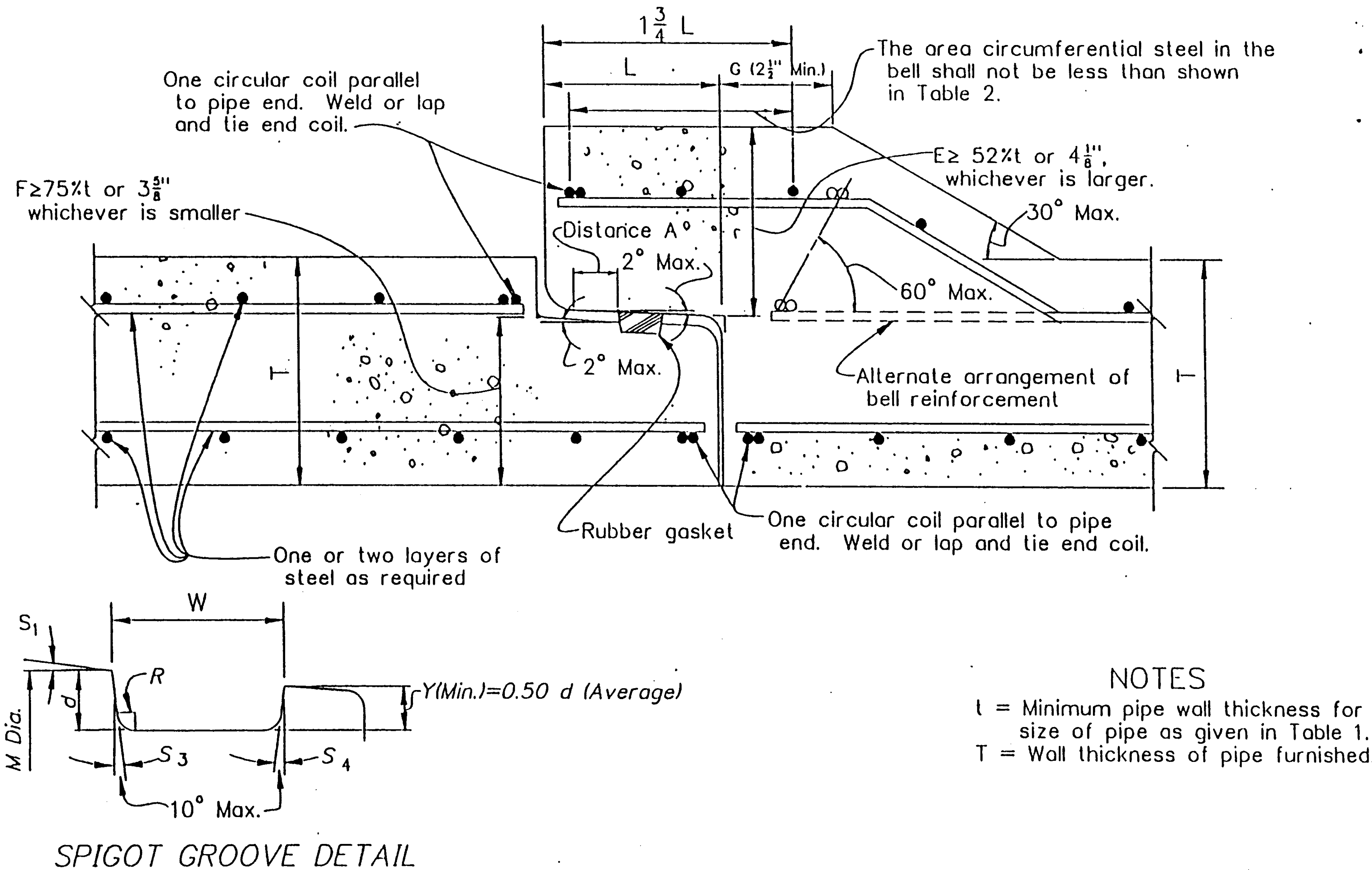
## NOTES

t = Minimum pipe wall thickness for size of pipe as given in Table 1.
T = Wall thickness of pipe furnished.
E ≥ t or $4\frac{1}{8}$" whichever is smaller.

# JOINT TYPE R-4

REINFORCED CONCRETE PRESSURE PIPE
( T = 2" TO $4\frac{1}{2}$" INCLUSIVE )

FIGURE 5




JOINT TYPE R−4

REINFORCED CONCRETE PRESSURE PIPE

( T = $4\frac{5}{8}$" AND LARGER )

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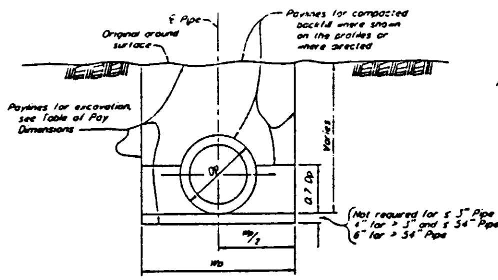
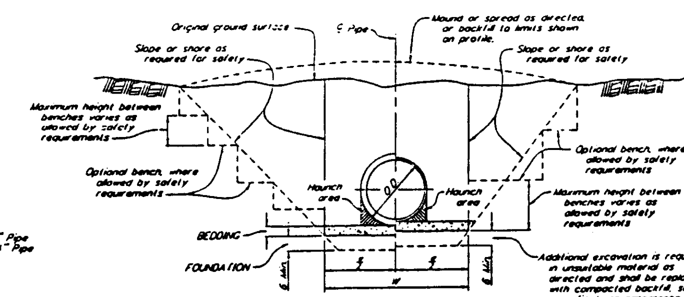


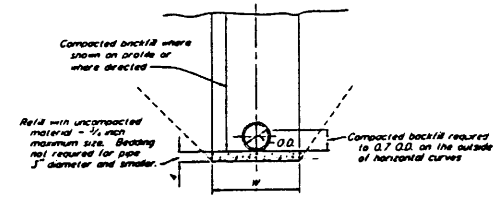

TRENCH FOR PAYLINES ONLY
ALL TYPES OF PIPE




HALF SECTION
RIGID PIPE

HALF SECTION
FLEXIBLE PIPE

TYPICAL TRENCH DETAILS




PIPE 10 INCH DIAMETER AND SMALLER

PVC
STEEL
DUCTILE IRON

TABLE OF PAY CIMENSIONS

| Pipe I.D. (inches) | Op (inches) | Wp (feet) |
|---|---|---|
| 6 and less | I.D. + 2 | 2.0 |
| Over 6 thru 18 | I.D. + 4 | $\frac{1}{12}$(I.D. + 24) |
| Over 18 thru 24 | I.D. + 4 | $\frac{1}{12}$(I.D. + 40) |
| Over 24 | 1.167 I.D. | $\frac{1}{12}$(1.167 I.D. + 36) |

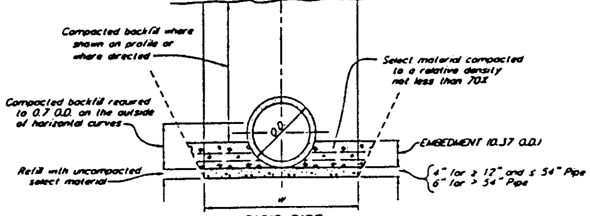
MINIMUM INSTALLATION WIDTH

| PIPE I.D. (INCHES) | W (FEET) |
|---|---|
| 6 and less | 2.0 |
| Over 6 thru 18 | $\frac{1}{12}$(O.D. + 20) |
| Over 18 | $\frac{1}{12}$(O.D. + 36) |

GRADATION LIMITS
FOR SELECT MATERIAL

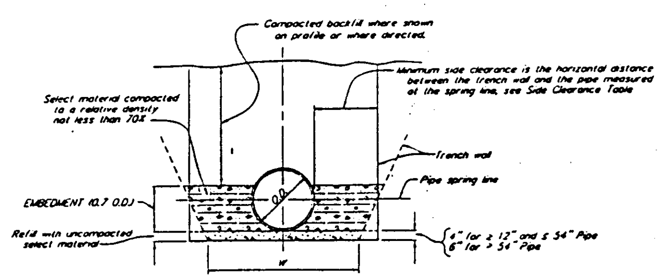
| SIZE * | PERCENT BY WEIGHT |
|---|---|
| Passing No. 200 sieve | 5 or less |
| Passing No. 50 sieve | 25 or less |

* Maximum size shall not exceed $\frac{3}{4}$ inch.




RIGID PIPE

DUCTILE IRON.................12" - 20"
REINFORCED CONCRETE..........12" AND LARGER
REINFORCED CONCRETE CYLINDER....48" AND LARGER




FLEXIBLE PIPE

PVC.....................12" - 36"
PRETENSIONED CONCRETE CYLINDER....12" - 66"
STEEL...................12" AND LARGER
FIBERGLASS..............12" AND LARGER
DUCTILE IRON............24" AND LARGER

SIDE CLEARANCE TABLE

| TRENCH TYPE | MINIMUM SIDE CLEARANCE (INCHES) |
|---|---|
| 1 | 10 INCHES FOR 12" THRU 18" I.D.<br>18 INCHES FOR OVER 18" I.D. |
| 2 | ONE OD |
| 3 | TWO OD |

For location of trench types, see Specifications.

## NOTES

Op and Wp are used for calculating pay quantities for all pipe and trench types. Calculations are based on vertical walls.
Paylines for backfill will be the paylines for excavation, except the volume of the pipe, based on the diameter Op will be deducted, and except where the depth of backfill is limited as shown on profiles.
W is minimum width of excavation in feet at bottom of bedding. The minimum side clearance for flexible pipe may require a wider trench bottom than dimension W.
Pipe diameters shown are the nominal inside diameter (I.D.) of the pipe in inches unless otherwise indicated.
O.D. is outside diameter in inches of the pipe actually installed.
Where pipe slope exceeds 0.1, see specifications paragraphs for backfill in pipe trenches.
Sloping, shoring, and benching shall be in accordance with Reclamation Construction Safety Standards.
Other installation methods with comparable pipe designs may be submitted for approval.

| | |
|---|---|
| 11/27/91 D- | REMOVED NOTES ABOUT EQUAL LIFTS UNDER "RIGID PIPE" AND "FLEXIBLE PIPE" |
| 10/17/90 D- LAK | REDRAWN WITH MINOR REVISIONS |

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

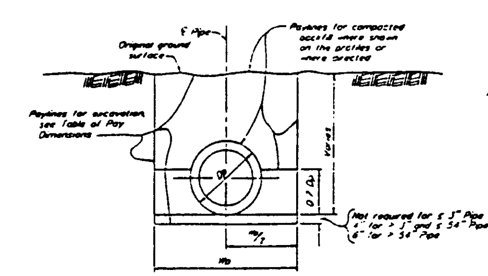
STANDARD DESIGNS

PRESSURE PIPE
TRENCH INSTALLATION
SELECT MATERIAL

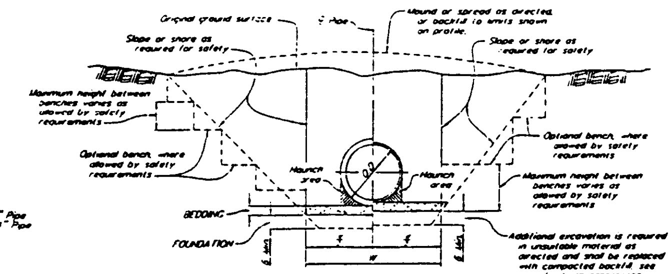
DESIGNED Richard P. Fuerst TECHNICAL APPROVAL Leo A. Kuncey, Jr.
DRAWN Bob Scully SUBMITTED Douglas M. Wegener
CHECKED Leo A. Kuncey, Jr. APPROVED W. L. [illegible]

40-D-6331

RICHARD FUERST, PE
PIPE SPECIALIST
USBR



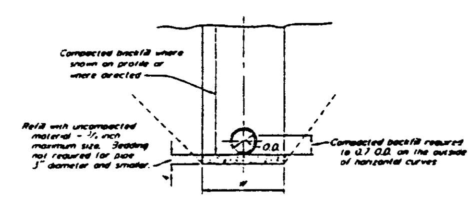

TRENCH FOR PAYLINES ONLY
ALL TYPES OF PIPE




HALF SECTION
RIGID PIPE

HALF SECTION
FLEXIBLE PIPE

TYPICAL TRENCH DETAILS




PIPE 10 INCH DIAMETER AND SMALLER

PVC
STEEL
DUCTILE IRON

## TABLE OF PAY DIMENSIONS

| Pipe I.D. (inches) | Op (inches) | Wp (feet) |
|---|---|---|
| 6 and less | I.D. + 2 | 2.0 |
| Over 6 thru 18 | I.D. + 6 | 1/12 (I.D. + 24) |
| Over 18 thru 24 | I.D. + 4 | 1/12 (I.D. + 40) |
| Over 24 | 1.167 I.D. | 1/12 (1.167 I.D. + 36) |

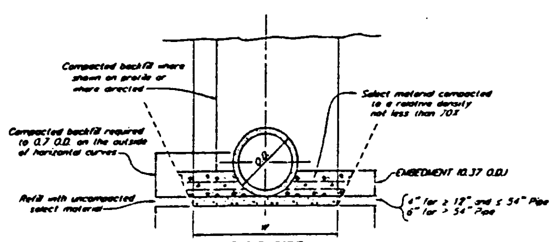
## MINIMUM INSTALLATION WIDTH

| PIPE I.D. (INCHES) | W (FEET) |
|---|---|
| 6 and less | 2.0 |
| Over 6 thru 18 | 1/12 (O.D. + 20) |
| Over 18 | 1/12 (O.D. + 36) |

## GRADATION LIMITS FOR SELECT MATERIAL

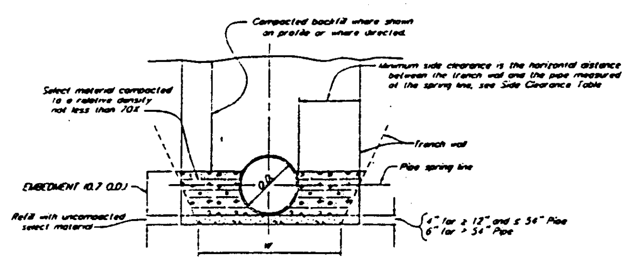
| SIZE * | PERCENT BY WEIGHT |
|---|---|
| Passing No. 200 sieve | 5 or less |
| Passing No. 50 sieve | 25 or less |

* Maximum size shall not exceed ¾ inch.




RIGID PIPE

DUCTILE IRON ............ 12" - 20"
REINFORCED CONCRETE ............ 12" AND LARGER
REINFORCED CONCRETE CYLINDER ............ 48" AND LARGER




FLEXIBLE PIPE

PVC ............ 12" - 36"
PRETENSIONED CONCRETE CYLINDER ............ 12" - 66"
STEEL ............ 12" AND LARGER
FIBERGLASS ............ 12" AND LARGER
DUCTILE IRON ............ 24" AND LARGER

## SIDE CLEARANCE TABLE

| TRENCH TYPE | MINIMUM SIDE CLEARANCE (INCHES) |
|---|---|
| 1 | 10 INCHES FOR 12" THRU 18" I.D.<br>18 INCHES FOR OVER 18" I.D. |
| 2 | ONE O.D. |
| 3 | TWO O.D. |

For location of Trench Types, see Specifications.

## NOTES

Op and Wp are used for calculating pay quantities for all pipe and trench types. Calculations are based on vertical walls.
Paylines for backfill will be the paylines for excavation, except the volume of the pipe, based on the diameter Op will be deducted, and except where the depth of backfill is limited as shown on profiles.
W is minimum width of excavation in feet at bottom of bedding. The minimum side clearance for flexible pipe may require a wider trench bottom than dimension W.
Pipe diameters shown are the nominal inside diameter (I.D.) of the pipe in inches unless otherwise indicated.
O.D. is outside diameter in inches of the pipe actually installed.
Where pipe slope exceeds 0.1, see specifications paragraphs for backfill in pipe trenches.
Sloping, shoring, and benching shall be in accordance with Reclamation Construction Safety Standards.
Other installation methods with comparable pipe designs may be submitted for approval.

REMOVED NOTES ABOUT EQUAL LIFTS UNDER "RIGID PIPE" AND "FLEXIBLE PIPE"

REDRAWN WITH MINOR REVISIONS

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

STANDARD DESIGNS

PRESSURE PIPE
TRENCH INSTALLATION
SELECT MATERIAL

DESIGNED Richard P. Fuerst

40-D-6551

## APPENDIX
## DESIGN CRITERIA FOR TABLES 1 AND 2

1. The designs for reinforced concrete pressure pipe presented in Table 1 are based on specific loadings, bedding conditions, and design requirements summarized in this appendix.

2. Loads. - The following loads are considered in the pipe designs:

   a. Dead load of the pipe, using unit weight of reinforced concrete of 150 pounds per cubic foot.

   b. Weight of water in the pipe, using inside pipe diameter and unit weight of water of 62.4 pounds per cubic foot.

   c. Earth load per lineal foot of pipe, based on a prism width equal to the outside diameter of the pipe, calculated from:

   $$We = He\ (O.D.)\ wFe$$

   where:

   We = effective earth load on pipe, pounds per lineal foot.
   He = height of earth cover over top of pipe, feet.
   O.D. = outside diameter of pipe, feet.
   w = unit weight of earth, set at 120 pounds per cubic foot.
   Fe = 1 + 0.2 (He/O.D.), 1.5 maximum.

   This earth load represents loose backfill in a trench of any width. For other earth load design assumptions, the alternate earth load may be compared to the above-design earth load, and the cover class (A through D) adjusted appropriately within the same pressure class.

   d. Internal pressure due to hydrostatic head measured from inside top of pipe to design hydraulic gradient. Classes listed in Table 1 represent hydrostatic head measured to horizontal centerline of pipe. Reinforcement designs presented do not include allowances for transient pressure surges (water hammer) in pipelines.

3. Bedding conditions. - Line bearing is assumed for dead load of pipe. Other loads are assumed to result in bearing over a 90-degree central angle. Pressure distribution, moments, and thrusts used in the pipe analyses are based on theory in Engineering Monograph No. 6 (Reference 6.a.).

4. Design requirements. - Reinforced concrete design is based on ACI 318 (Reference 6.b.) and AASHTO specifications (Reference 6.c.), using a 28-day design compressive strength (f'c) of 4,500 pounds per square inch, reinforcement yield strength of 40,000 pounds per square inch, a load factor

of 1.8, and a capacity reduction factor of 1.0, except no stirrups are used even though required by references for some pipe classes.

a. Minimum steel area. - Calculated for hydrostatic head only. Allowable tensile stress in reinforcement is:

$$fs = 17{,}000 - 35\ Hw$$

where:

fs = allowable tensile stress, pounds per square inch.
Hw = hydrostatic head, feet.

For elliptical reinforcement, minimum steel area is 1.6 times the minimum area required for single-cage circular.

b. Maximum steel area. - Limited by concrete compressive stress and calculated from AASHTO.

c. Design concrete cover. - For single-cage reinforcement, steel is assumed to be at centerline of cross section, except for elliptical shape at pipe invert. For double-cage reinforcement and for elliptical shape at pipe invert, design cover is assumed at values given in these specifications at subparagraph 2.b.

5. The minimum bell reinforcement presented in Table 2 is based on:

a. Hydrostatic head is assumed to act on a length of 1.75 inches around the internal circumference of the bell.

b. The gasket is assumed to exert a pressure of 200 pounds per linear inch around the internal circumference of the bell.

c. The allowable tensile stress in reinforcement is as given in subparagraph 4.a. above.

6. References. -

a. Olander, H. C., Stress Analysis of Concrete Pipe, Engineering Monograph No. 6, U.S. Bureau of Reclamation, Denver CO, October 1950.

b. ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318), American Concrete Institute, Detroit MI.

c. Standard Specifications for Highway Bridges, Section 17, American Association of State Highway and Transportation Officials, Washington D.C.